VEGETATIVE PROPAGATION OF *Cynodon dactylon* (L.) Pers. cv Coastcross-1 FROM STEMS

By

HEKO W. KOSTER

A DISSERTATION PRESENTED TO THE GRADUATE COUNCIL OF
THE UNIVERSITY OF FLORIDA
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE
DEGREE OF DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

1976

Dedicated to Ceres,

Goddess of Agriculture

ACKNOWLEDGEMENTS

The author expresses his sincere gratitude to his chairman, Dr. G. O. Mott, for his guidance throughout his Ph. D. program. To Dr. M. H. Gaskins, research advisor of the Supervisory Committee, the author is most grateful for his immediate interest and enthusiasm in this research project. The author wishes to thank the other members of the Committee, Dr. D. E. McCloud for his encouragement to start this Ph. D. program and Dr. C. B. Ammerman and Dr. W. W. McPherson for their professorial assistance.

Appreciation is expressed to Dr. J. M. Davidson, Dr. L. C. Hammond, Mr. R. E. Jessup, Dr. R. C. Littell, Ms. Carol Lynn, Mr. Dan F. Mahnks, Dr. F. G. Martin, Dr. R. E. Rodgers and Dr. O. C. Ruelke for advise and assistance given during the research and/or the courses.

Appreciation is expressed to Ir. P. R. Bouman, Prof. Dr. Ir. P. Buringh, Ir. J. G. P. Dirven and Prof. Ir. M. L. 't Hart for the agronomic training of the author during his study in Wageningen.

Appreciation is also extended to Ms. Margaret Glenn, Ms. Peggy Pascal and Ms. Vickey Vich for their help in the laboratory and office. Mr. Gerald C. Spivey, Manager of the Agronomy Farm, Cathy Felice, Mary, Mel, Molly, Virginia and Wendy, the 1975 migrant workers, are thanked for their cooperation and their help in the field under the hot sun.

A special word of thanks is extended to Ms. Patty Evans for her dedication shown with the weighing of the many samples and to Mrs. Janet

Eldred for her immaculate typing of the final manuscript from a hand-written draft.

The author is grateful to the Department of Agronomy and Center for Tropical Agriculture of the University of Florida for providing financial assistance during his study.

A debt of gratitude is owed to the author's wife, Ankie, for her love and understanding and for her sacrifice given to cope with gaps left in the family by a man working most of the day. The author thanks his sons, Michiel and Adriaan, for their understanding acceptance of his neglect imposed on them.

Last but not least, the author thanks his parents, Heko K. and Han, for their perpetual interest and support given to his education.

TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENTS	iv
LIST OF TABLES	ix
ABSTRACT	xiii
CHAPTERS	
I GENERAL INTRODUCTION	1
II LITERATURE REVIEW	5
Macromorphology of Grass Stems	5
Origin and Branching of Stems	5
Stem or Stolon Types	5
Axillary Buds, Root Primordia and Adventitious Roots	6
The Development of a Stem Cutting to a New Plant	7
Root Types and Root Development	8
Bud Germination and Root Development	9
Effects of Drying, Heat and Submergence on Plant Material	10
Drying and Heat	10
Submergence	11
Cutting Size, Planting Depth and Position	12
Cutting Size	12
Planting Depth	13
Position of the Cutting after Planting	13
Preplant Treatments with Growth Regulators	14
Effect of Ethylene on Growing Grass Stems	14
Use of Ethylene on Cuttings	15
Use of Other Growth Regulators on Cuttings	16

TABLE OF CONTENTS (Continued)

		Page
III	PLANT MATERIAL QUANTITY AND MACROMORPHOLOGY	18
	Introduction	18
	Materials and Methods	19
	The Source of the Plant Material and Metrological Data	19
	Field and Lab Procedure	19
	Macromorphology of the Plant Material	22
	Quantity of the Plant Material	23
	Results and Discussion	24
	Macromorphology and Weight of Stems in Plant Materials of Different Age	24
	Relationships Between Macromorphological Characteristics	27
	Stem Classes and Their Characteristics	30
	Plant Material Quantity and Distribution over Stem Classes	38
VI	MACROMORPHOLOGY AND PROPAGATING CAPACITY	44
	Introduction	44
	Materials and Methods	44
	Comparing the Propagating Capacity	44
	Propagule Types	45
	Soil Moisture Regimes	46
	Planting of the Pot	48
	Statistical Analyses	49
	Results and Discussion	49
	Four-Week-Old Plant Material	49
	Seven-Week-Old Plant Material	53
	Twelve-Week-Old Plant Material	54
V	ETHREL EFFECTS ON PROPAGATING CAPACITY	56
	Introduction	56
	Materials and Methods	57
	Plant Material, Ethrel Treatment and Lay-Out	57
	Studies under Intermittent Mist	58
	Studies under Field Conditions	59
	Statistican Analyses	60

TABLE OF CONTENTS (Continued)

	Page
Results and Discussion	60
Studies under Mist	60
Weight of the emerged roots per planted propagule	64
Weight of the emerged roots per propagule with emerged roots	64
Propagules with emerged roots	64
Weight of emerged buds per planted propagule	64
Weight of emerged buds per propagule with emerged buds	65
Propagules with emerged buds	65
Main findings	65
Studies under Field Conditions	66
Weight per planted propagule	66
Weight per living propagule	70
The percentage of growing propagules and the percentage of propagules with emergence of buds situated above the soil	70
Propagules with emergence of buds situated below the soil surface	71
Propagating capacity	71
VI SUMMARY AND CONCLUSIONS	73
GLOSSARY	82
APPENDICES	87
REFERENCES	110
BIOGRAPHICAL SKETCH	113

LIST OF TABLES

Table		Page
1	Data collection scheme for the study of the macro-morphology and quantity of plant material at different ages	21
2	Characteristics of living stems in plant material of different ages	25
3	Percentage of living stems with emerged roots and/or buds and/or three leaves on one node in plant material of different ages	26
4	Correlations among morphological characteristics of stems in 4-week-old plant material	28
5	Correlations among morphological characteristics of stems in 7-week-old plant material	28
6	Correlations among morphological characteristics of stems in 12-week-old plant material	29
7	Length, diameter, number of nodes and frequency of stems with or without emerged roots, buds and nodes with three leaves in 4-, 7- and 12-week-old plant material	31
8	Defined limits of the stem classes in 4-week-old plant material	32
9	Defined limits of the stem classes in 7-week-old plant material	33
10	Defined limits of the stem classes in 12-week-old plant material	34
11	Characteristics of stems of different classes in 4-week-old plant material	35
12	Characteristics of stems of different classes in 7-week-old plant material	36
13	Characteristics of stems of different classes in 12-week-old plant material	37

LIST OF TABLES (Continued)

Table		Page
14	The quantity of plant material after different regrowth periods	39
15	The macromorphological composition of 4-week-old plant material in terms of its distribution over stem classes	40
16	The macromorphological composition of 7-week-old plant material in terms of its distribution over stem classes	41
17	The macromorphological composition of 12-week-old plant material in terms of its distribution over stem classes	42
18	Main distinctive characteristics of propagule types studied	47
19	Propagule development 14 days after planting of four propagule types found in 4-week-old plant material	50
20	Propagule development 14 days after planting of four propagule types found in 7-week-old plant material	51
21	Propagule development 14 days after planting of four propagule types found in 12-week-old plant material	52
22	Effect of Ethrel treatment on emergence and development of 4-week-old plant material under mist	61
23	Effect of Ethrel treatment on emergence and development of 7-week-old plant material under mist	62
24	Effect of Ethrel treatment on emergence and development of 12-week-old plant material under mist	63
25	Effect of Ethrel treatment on emergence and development of 4-week-old plant material under field conditions	67
26	Effect of Ethrel treatment on emergence and development of 7-week-old plant material under field conditions	68
27	Effect of Ethrel treatment on emergence and development of 12-week-old plant material under field conditions	69

LIST OF TABLES (Continued)

Table		Page
28	Summary of effect of Ethrel on the propagating capacity of plant material of three ages planted at different dates in the field	72
A-1	Propagule types in 4-week-old plant material, description and weight of stempart and buds at planting	94
A-2	Propagule types in 4-week-old plant material, description and weight of roots at planting	95
A-3	Propagule types in 7-week-old plant material, description and weight at planting	96
A-4	Propagule types in 7-week-old plant material, description and weight at planting	97
A-5	Propagule types in 12-week-old plant material, description and weight of stem part and buds at planting	98
A-6	Propagule types in 12-week-old plant material, description and weight of roots at planting	99
A-7	Propagule types in 4-week-old plant material, description and weight of apex and buds during growth and/or 14 days after planting under two different moisture regimes	100
A-8	Propagule types in 4-week-old plant material, description of roots and stem parts 14 days after planting under two different moisture regimes	101
A-9	Propagule types in 7-week-old plant material, description and weight of apex and buds during growth and/or 14 days after planting under two different moisture regimes	102
A-10	Propagule types in 7-week-old plant material, description and weight of roots and stem part 14 days after planting under two different moisture regimes	103
A-11	Propagule types in 12-week-old plant material, description and weight of apex and buds during growth and/or 14 days after planting under two different moisture regimes	104

LIST OF TABLES (Continued)

Table		Page
A-12	Propagule types in 12-week old-plant material, description and weight of roots and stem part 14 days after planting under two different moisture regimes	105

Abstract of Dissertation Presented to the Graduate Council
of the University of Florida in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy

VEGETATIVE PROPAGATION OF
Cynodon dactylon (L.) Pers. cv Coastcross-1 FROM STEMS

By

Heko W. Koster

June, 1976

Co-chairmen: Gerald O. Mott
Murray H. Gaskins
Major Department: Agronomy

Stems in plant materials of three ages were classified according to macromorphological criteria. The effect of age on the quantity and composition of the plant material was studied. Field and greenhouse propagating experiments were conducted, and the resulting data analyzed to correlate propagating capacity with stem macromorphology. In addition, the effect of Ethrel treatments on the propagating capacity of plant material was studied.

Increasing age of plant material resulted in a sharp decline in the number of living stems and in an increase in the dry weight and the number of nodes of the living plant material. Within age groups, stems of very different macromorphology occurred. Length, maximum diameter, number of nodes, number of nodes with emerged buds or roots or three leaves and weight of stems increased with age.

Macromorphological stem classes were defined in plant material of 4, 7 and 12 weeks. Large differences were found in mortality, leaf growth and root development between cuttings from different classes of stems. Development after planting was positively related to maximum

stem diameter, emergence of roots and other stem characteristics, which distinguished the stem classes. Thick stems were much superior to thin stems as propagating material under all growing conditions tested. The stem section from which cuttings were derived influenced development also.

Stems with two or less nodes and diameters less than 1.3 mm developed slowly after planting even under optimum soil moisture. These stems comprised 75% of the stems, 42% of the weight and 64% of the nodes of 4-week-old plant material.

Stems with diameters less than 1.6 mm and without emerged buds or roots comprised 60% of the stems, 30% of the weight and 50% of the nodes of 7-week-old plant material. Stems with diameters of 1.6 mm or larger accounted for 20% of the stems, 50% of the weight and 30% of the nodes of this material.

Stems with diameters less than 1.6 mm and without emerged buds or roots comprised 25% of the 12-week-old plant material. Stems with a maximum diameter between 1.6 and 2.1 mm comprised another 25% of this material. The remainder of the material consisted of approximately equal parts of stems with diameters less than 1.3 mm or larger than 2.1 mm.

Submergence of cuttings for one minute in 1000 ppm Ethrel increased root weight on mist-grown cuttings. Thirty to 100 ppm Ethrel increased weight of field-grown plants. Cuttings treated with 3000 or 10,000 ppm Ethrel developed less well than untreated cuttings. Ethrel treatment effects were observed on five different plant materials. Maximum positive responses were observed in three of these materials from Ethrel

levels of 300 and 1000 ppm. These levels gave negative responses in the other two materials.

Initially the propagule stems were integral parts of the new plants and were the only tissue connecting roots and leaves. The growth phase in which this condition prevailed was, however, invariably a short term one (about 6 weeks). Later, new rooted shoots developed from axillary buds. At that point, the propagule stem lost its significance as part of the new plant.

CHAPTER 1
GENERAL INTRODUCTION

Vegetative propagation is a common method of establishing pastures in the wet and monsoonal tropics and the wet summer subtropics. In these climates establishment from vegetative material has certain advantages over the use of seed apart from the fact that several forage grasses do not produce any significant quantities of viable seed. Actively growing stems are generally used as plant material. These can be cut and collected from an established pasture in exactly the same way as a hay cut is made. After cutting, the green stems or stem pieces are worked partly into the soil of the area to be planted. The new plants arise from axillary buds or shoots located on the nodes of the cut stems.

In general, vegetative propagation is considered to be a simple seldom failing technique to establish pastures. Obviously there is more to it as several newly developed superior lines, e.g., in the Paspalum and Digitaria genera, are presently doomed to remain in small plots as they are difficult to propagate vegetatively. Also, the different ability of gramineous forage species to establish from stem cuttings under adverse moisture conditions is well known, particularly in areas with a pronounced wet and dry season. In such regions it is common to plant early in the wet season when the preparation of the soil and further planting operations are not hampered by excessive wetness of the field. However, at that time of the year there is a certain

risk that new plantings will be subjected to unexpected dry spells during which soil moisture conditions will not be optimal for quick germination and development of the propagules. The last is crucial: a) as the newly planted grass has to compete with an abundance of new weeds sprouting from seeds activated by the last soil cultivation; and b) as in the end the development of the planted grass compared to the development of the weed population determines the success or failure of the new planting.

The complex of interrelated factors which governs the developments of grass propagules can be grouped together and subdivided as follows:

Propagule characteristics at time of planting:

Characteristics of plant material at time of harvest

Genetical (species, cultivar)
Chemical (water, inorganic and organic reserves)
Physical (resistance to desication and other stresses)
Physiological (activity and maturity of tissues)
Morphological (axillary bud, root development)
Phyto-sanitarial (insect or disease infections)

Propagule preparation from plant material

Stempart (base vs. center vs. top)
Propagule size (one or more nodes, complete stem)

Change in propagule (plant material) characteristics prior to planting--post-harvest pre-plant time interval and conditions

Planting technique:

Depth of planting
Inclination of stem
Contact of propagule with soil
Position of axillary buds after planting (at lower or upper side of propagule)

Growth conditions after planting:

Moisture content and temperature of soil and air
Soil compaction and aeration
Plant nutrient availability

Insects and diseases
Development of weeds, etc.

Very little information could be found on any of the above listed factors and it was concluded that hardly any studies have been conducted on the properties of vegetative plant material of tropical forages, or on the effects of the individual growth factors determining the development of pastures from such material.

The decision was made to study one cultivar in detail with the objective to

1. Determine the component stem characteristics of harvested plant material.
2. Assess differences in propagating capacity among stems different in macromorphology.
3. Determine the effect of treatment of the plant material with a growth regulator upon the propagating capacity.
4. Assess changes with age upon the components and the quantity of plant material.

Any tropical grass which is normally propagated vegetatively could have been used for the above outlined study. It was decided to execute the study on Cynodon dactylon cv Coastcross-1, a sterile hybrid. Coastcross-1 is generally established by broadcasting green stems cut at the hay stage and disking these into moist soil (Burton, 1972).

By the end of the study a better insight had been obtained of the development of a propagule into a plant. This by itself had not been a specific objective of the study. The conclusions obtained were of a general character and were not subjected to statistical analyses. As the subject by itself was of interest these conclusions are presented in an appendix.

Previous to the study, a few preliminary tests on the effects of growth regulators on cuttings of several grasses, including Coastcross-1, were executed. The results of these tests are also presented in an appendix.

CHAPTER 2
LITERATURE REVIEW

Macromorphology of Grass Stems

Origin and Branching of Stems

Grass stems are also referred to as shoots. Their origin was described by Evans (1958). The grass shoot originated directly from the embryo in a seed or it developed as a branch from a bud. The bud originated from meristematic tissue at the base of a phytomer in the axil of the leaf which crowned the phytomer next below. Gould (1968), describing the branching of stems, noted that branching at the base of the culm produced erect lateral shoots; horizontal, above ground stolons or subterranean rhizomes. In a creeping sod-forming grass such as Cynodon dactylon (L.) Pers. the branching continued indefinitely with only part of the stems terminating in an inflorescense. Lateral shoots, including stolons, rhizomes and vegetative branches at the upper culm nodes differed only in origin. Stolons of Cynodon dactylon (L.) Pers. were found to be similar to the erect culms in leafiness and general appearance.

Stem or Stolon Types

Bogdan (1952), describing the stoloniferous grasses in Kenya, distinguished two different types of stolons: the Digitaria type and the Cynodon type. On the Cynodon type stolons the leaves were in groups of

two to six (usually four) and the leaf bases of each group appeared to arise from a single node. These nodes can be regarded, however, as compound nodes or as groups of nodes with very short undeveloped internodes between them. The branching of a compound node began from the axil of the lowest leaf on that node. The young branch pressed the leaf sheath from the stem. After this the stem was still protected by the sheaths of the upper leaves of the same compound node. The second branch of the same node started from the axil of the next leaf until only two (or sometimes one) upper sheaths remained pressed against the stem. The basal part of the internode, protected by these leaves, remained soft and proceeded to grow for up to several days after the beginning of the branching. Thus, the branching in the Cynodon type stolons did not depend on the longitudinal growth of internodes, but branching began any time after the appropriate node had been fully formed.

In Cynodon plectostachyum (K. Schum.) Pilger, as well as in many other species with Cynodon type stolons, branching began at an early stage of development of the upper internodes and, therefore, in the growing part of the stolon, very near the apex.

Axillary Buds, Root Primordia and Adventitious Roots

Stiff and Powell (1974), studying the stem anatomy of 20 grasses, noted that variation in the number of leaves and axillary buds occurred primarily in young (compound) nodes at the base of stems. Their results indicated that compound-node formation appeared to be under some genetic control, but it was very responsive to environmental changes. Of the 10 nodes of Coastcross-1 which they studied, six nodes had two leaves and one bud per node, the other four nodes had three leaves and

two buds per node. Barnard (1964) who described the form and structure of grasses, mentioned that in species with stolons, adventitious roots developed at nodes associated with short internodes. Van Dillewijn (1952) describing Saccharum officinarum L. noted that, in the basal region of each internode of sugarcane, root primordia occurred all around the stem in a so called root band situated above the connection of the leaf to the node and below the intercalary meristem. The number of root primordia was found to be a varietal characteristic. On mature cane nodes it ranged from 30 to as many as 123. The number of root primordia per node was further affected by external factors and the age of the node. The axillary bud on the sugarcane node was always located in the root band. Stiff and Powell (1974) studying grass stems also found adventitious roots located on the node adjacent to the axillary bud.

Both Barnard (1964) and Stiff and Powell (1974) noted that the axillary bud and the root primordia on a node were connected with the vascular system of the stem. No instance was reported of adventitious buds in grasses.

The Development of a Stem Cutting to a New Plant

When a stem cutting is planted, the axillary bud and the adventitious roots on the node develop together into a new plant. In none of the publications dealing with form, structure and development of forage and turf grasses was this development discussed. It has been studied in detail for sugar cane which is planted from stem cuttings.

Root Types and Root Development

Van Dillewijn (1952) reviewed the botany of sugarcane and discussed the type, development and fate of different roots on cane cuttings. The first roots developed from the primordia on the rootband. These roots, here to be called cutting roots, were thin and much branched. Later roots arose from the lower nodes of the shoot, developed from the axillary bud. These roots, which are designated shoot roots, were thick, fleshy and less branched. During the first month the germinating stem cutting depended almost entirely on the cutting roots for its intake of water and nutrients. During the second and third month the nutrient and moisture uptake shifted from the cutting to the shoot roots. At the end of the third month and thereafter nutrients and moisture were taken up mainly by the shoot roots and the cutting roots started to decay.

Venkatraman and Thomas (1922) found that the number of cutting roots developed within 10 days after planting varied for sugarcane clones from 11 to 28, whereas in Saccharum spontaneum L. only 2.3 cutting roots developed in that period. They concluded that the number of cutting roots depended on the number of root primordia present in the rootband and on the percentage of root primordia that actually developed into roots. Not all root primordia took part in the early formation of cutting roots. Both Weller (1927) and Dutt (1934) found that the dormant root primordia could be forced to activity and development by cutting off the earlier germinated cutting roots. If this was done repeatedly new adventitious root primordia, which developed into roots, were initiated in the rootband.

Bud Germination and Root Development

The roots and shoots of stem cuttings do not always develop or do not develop simultaneously. Van Dillewijn (1952) reported that early studies showed that a bud on a sugarcane cutting did not germinate until at least one cutting root was developing. However, in later studies it was found that a bud was able to germinate when all cutting root primordia had been removed although its full development was impeded by the operation. Van Dillewijn reported too that both the germination percentage and the speed of germination of buds varied with the position of the bud on the cane stalk. Of the buds on the top five nodes, 44 to 50% germinated 11 to 13 days after incubation, whereas for the lowest 11 nodes 25 to 36% of the buds germinated 19 to 30 days after incubation. In cuttings containing three nodes the roots developed first at the basal nodes while shoot development started at the upper node.

Fuller (1973) found in germination tests with rhizome cuttings of common bermudagrass that on 93% of the cuttings only a shoot developed and no roots. An explanation could not be offered. Heideman and Van Riper (1967) in laboratory tests with Panicum virgatum L. found 40 to 70% bud germination of stem cuttings harvested in the period from April through August. At both earlier and later dates less than 30% bud germination was observed.

Van Dillewijn (1952) reported that germination of the axillary buds of sugarcane cuttings was increased by heavy applications of nitrogen prior to harvest of the stems. Johnson (1958) found that nitrogen application in late spring resulted in an immediate stimulation of bud

activity on Agropyron repens (L.) Beauv. rhizomes. Johnson (1958) reported that bud dormancy at that time of year was probably caused by low levels of nitrogenuous constituents in the rhizomes.

Van Dillewijn (1952) reported that the emergence of bud or roots on stem cuttings was affected by the angle at which a cutting is stored and/or planted. One-node stems or cuttings of Sorgum vulgare Pers. developed a shoot in the first week when placed vertically, only in the second week when placed horizontally the reverse was true for the cutting roots. In Formosa it was found that cuttings planted horizontally rooted freely when derived from horizontally stored canes. Little or no root formation occurred on canes which were stored upright. Gaskins and Almeyda (1972) studying the vegetative propagation of bamboo observed similar phenomena.

Effects of Drying, Heat and Submergence on Plant Material

Drying and Heat

Madison (1971) has pointed out that careful scheduling is needed when planting stolons of turfgrasses. Deterioration of the plant material is rapid, as stolons will lose moisture when spread out, or will heat if deeply piled. Usually they are cooled by icing or by spraying with cold water. In a shaded, moist and ventilated area, stolons can be kept up to 6 days. Chiles and co-workers (1966) concluded that maintaining the moisture content of bermudagrass rhizomes was a major requirement for successful storage. They found that when the moisture content of the rhizomes was reduced from 40 to 10% in a 16-day period the germination dropped from 90 to 35%. Germination remained at 90%

throughout 16 days of storage if the stolons were kept moist by sprinkling on alternate days. Also, Horowitz (1972) observed that moisture loss caused a decrease in germination of bermudagrass rhizome sections. One node section lost its capacity to germinate when dried 7 days. In this period the section lost 53% in weight. The critical moisture content for survival was 15%; submergence in water did not affect subsequent germination capacity. Grether (1967) found that stolons of turf grasses at 37°C should be watered within 15 minutes after planting, within 20 minutes at 32°C, within one half hour at 27°C, 1 hour at 21°C and 2 hours at 16°C.

Submergence

With the planting of sugarcane the standard commercial procedure at present, according to Barnes (1974), is to dip both ends into a fungicidal solution.

Van Dillewijn (1952) reported that in several areas it was common practice to soak cane cuttings in cold running water during 12 to 48 hours. Soaking seemed to yield the best results on cuttings of the middle and lower part of the stem. This was especially true when the conditions after planting were suboptimal due to insufficient soil moisture and/or low temperatures. Hot water treatment of cane cuttings, 20 minutes at about 52°C, increased both axillary bud and cutting root development; however, the range of water temperature and treatment duration is narrow.

Khan and Hall (1954a), studying growth regulator treatments on cane cuttings, also noted that 24 hour soaking in water increased bud germination and root development. Some growth regulators, to be

discussed later, improved rooting still further as compared to soaking in water.

Cutting Size, Planting Depth and Position

Cutting Size

Several authors have reported that cuttings having more than one node were superior to cuttings of one node (Bernal, 1971; Horowitz, 1972, Van Dillewijn, 1952). Van Dillewijn (1952) reported for sugarcane that the minimum volume required for germination is amazingly small. Plants were obtained from parts of a node containing only the bud and one root primordium. However, the more nodal and internodal tissue included in the cuttings of one node, the better was their early development. Cane cuttings of more than one node exhibited a marked polarity; the roots developed first at the basal internodes while shoot development started at the top node. Van Dillewijn concluded that the minimum length of cuttings is largely dictated by the condition of the seed cane, the growing environment and the care given to the young plants. In Java where the temperatures are high, cuttings having two or even one node with an emerged bud are used when the seedbed is irrigated. In Louisiana autumn planting of five node cuttings gave the best yield (Arcenaux, 1948). In Taiwan it was found that under severe growing conditions cuttings with four to six nodes had a higher percentage germination than shorter ones (Chew, 1950). Under greenhouse conditions Khan and Hall (1954a) found that the root weight and root volume produced by cuttings having one, two, three or four nodes decreased with increasing number of nodes; the number of roots produced increased with increasing number of nodes.

Planting Depth

Van Dillewijn (1952) reported that under favorable conditions a light or no soil covering of cane cuttings gave the best germination. He remarked that in all cases of shallow planting, care must be taken to maintain a favorable soil moisture condition by frequent but light irrigations. It was found in pot experiments that cuttings covered with 2.5, 7.5 and 12.5 cm of soil had a germination percentage of 96, 93 and 51%, respectively. Chiles and co-workers (1966) planted 3-node rhizome cuttings of bermudagrasses horizontally at different depths, and observed a general decrease of the number of emerged plants with depth. At 31 days after planting, 70% of the cuttings planted at zero cm had germinated, and only 40% of those planted 10 cm below the soil surface. Shallow planting resulted in faster shoot emergence.

Position of the Cutting after Planting

A general recommendation for planting of turfgrasses is that at least one node of the cutting must be below ground and the top of the cutting with leaves above ground so that top growth can resume (Sprague, 1970). It is quite apparent from several studies that contact between roots on nodes below the ground and growing buds on nodes above the ground is maintained (Van Dillewijn, 1952). In one of these studies cane cuttings were grown with a bud developing from a node above ground which was dependent for water and nutrients from the cutting roots on a node below ground. Such cuttings were grown successfully over 7 months following planting. All water and nutrients absorbed by the roots had to pass through the cutting, thus rendering the cutting an essential and living part of the plant.

Preplant Treatments with Growth Regulators

Effect of Ethylene on Growing Grass Stems

Zimmerman and Hitchcock (1933) observed that popcorn plants (Zea mays L. var everta Bailey) treated for 5 days with 0.2% acetylene produced roots from five nodes above the ground whereas controls showed a start of roots from only the basal node. Abeles (1973) reported that ethylene can cause root primordia to initiate growth.

Preliminary experiments in 1940 showed that treatments of cane cuttings with acetylene resulted in quicker bud germination (Van Dillewijn, 1952). Vlitos (1974) reported that Ethrel (2-chloroethylphosponic acid) treatment of growing cane resulted in activation and/or development of axillary buds, tillers and brace roots. McAffee (1973) found a great increase in tillering of Poa pratensis L. as one of the effects of Ethrel application. He reported a large tolerance in safety of several temperate grasses to Ethrel. A single application of 36 kg/ha or three applications of 9 kg/ha in one growing season did not produce adverse effects.

Domir and Foy (1974) found that the ethylene evolution from Ethrel, applied to tobacco leaf discs, was maximum during the first day and leveled off on the fourth day. Of the total ethylene evolved during the first 4 days, more than 50% evolved within 24 hours after Ethrel application. These experiments showed that the ethylene formed after application of acetylene or Ethrel to growing gramineous plants can overcome apical dormancy and activate lateral buds. These results from the short term exposure of the plant to Ethrel-released ethylene are in accordance with the conclusions of Phillips (1975) for broadleaved plants.

Continuous exposure of intact plants to ethylene inhibited growth of the main apex, but did not stimulate growth of lateral buds. In contrast, a pulse treatment with ethylene for 1 to 2 days was followed by growth of axillary buds (Phillips, 1975).

Use of Ethylene on Cuttings

The use of ethylene or ethylene releasing compounds with the vegetative propagation of grasses has been investigated. Hovin and coworkers studying the propagation of Phalaris arundinacea L. tested the effect of Ethrel on three clones. Stem cuttings of 10 cm length were soaked for 1 minute in 0, 100, 500 and 1000 ppm aequous solutions of Ethrel before field planting. After 11 days the number of emerged shoots was recorded. Each Ethrel concentration had increased the emergence of one clone, whereas they reduced it of another clone. In the third clone the 100 and 500 ppm Ethrel resulted in an increase in emergence and the 1000 ppm in a decrease. Khan and Hall (1954a) found a slight increase in bud development, but a decrease in root development, on sugarcane cuttings grown after having been exposed to 100 ppm ethylene gas during 18 hours. Swanson (1974) cited several studies of Ethrel as an aid in rooting of dicotyledoneous plants and pointed out that conflicting results were obtained in these studies; the response to Ethrel varied between species and between cultivars. No hypotheses exist as to what the underlying causes of these different results may have been. Wtih the varieties where positive results were obtained, no certainty exists that the results would have been the same under different circumstances. The studies indicate that positive effects from Ethrel treatment of grass cuttings are possible, but for practical

application further testing would be required. Apart from ethylene and related compounds, a few other growth regulators have been tested with the vegetative propagation of grasses.

Use of Other Growth Regulators on Cuttings

Khan and Hall (1954a) grew cane cuttings over a period of 21 days after submergence during 24 hours in solutions of two growth regulators at various concentrations and in different combinations. The amine salt of alpha-ortho-chlorophenoxypropinonic acid (alpha-O-CPA) had an optimum concentration for propagation at 10 ppm and for indoleacetic acid (IAA) this optimum was 100 ppm. Higher concentrations of both growth regulators gave maximum rooting responses but reduced bud germination. With a mixture of nine parts of IAA 100 ppm and one part of alpha-O-CPA 100 ppm propagation was maximal, viz. bud inhibition was minimized and rooting responses positive. The growth medium used in these experiments was sterilized sand. Using the same experimental procedure the effect of nitrogen application upon planting was tested. The nitrogen increased the root weight in all treatments, and this was particularly evident when the cane cuttings had received preplant growth hormone treatments (Khan and Hall, 1954b). It was also found that cuttings from the center of the cane stalk responded most to growth regulators (Khan and Hall, 1954a). Hoveland (1963) tested the use of 3-indolebutyric acid (IBA) with the propagation of bermudagrasses by dipping the end of the cuttings in talcum power containing IBA. The rooting of Suwannee bermudagrass was improved by 0.3 and 0.8% IBA talcum, which greatly reduced the bud germination. The 0.1% IBA had opposite effects. The rooting of Coastal bermudagrass cuttings was increased by each of the previously mentioned

IBA concentrations. IBA did not have any adverse effects on the bud germination of Coastal bermudagrass.

The findings of these studies can be summarized by saying that IAA, IBA and alpha-O-CPA were found in several instances to improve root development, generally this was coupled with a reduction of bud growth. The growth regulator effect was found to vary depending on variety, stem section and growth medium.

CHAPTER 3
PLANT MATERIAL QUANTITY AND MACROMORPHOLOGY

Introduction

In view of the limited knowledge of the macromorphology of the individual stems, which collectively form the plant material, a macromorphological inventory of the stems in the plant material was made together with weight determination. This was done after each of three different regrowth periods; the first after 4 weeks, the second after 7 weeks and the third after 12 weeks.

The objectives were the following:

1. To determine the range of macromorphological characteristics of stems occurring within the plant material harvested at the end of each growth period.

2. To detect possible relationships among macromorphological characteristics.

3. To define macromorphological stem classes which were associated with differences in propagating capacity.

4. To determine the total quantity of plant material per m^2 in a pasture.

5. To specify the macromorphology of plant material in quantitative terms by determining the distribution of its stems over different stem classes.

6. To determine the effect of different regrowth periods upon the macromorphology and the quantity of the plant material.

Materials and Methods

The Source of the Plant Material and Meterological Data

Stems were obtained from a practically weed-free 3-year-old stand of Cynodon dactylon (L.) Pers. cv Coastcross-1 at the Agronomy farm in Gainesville, Florida, on Arredondo loamy fine sand. Over the past years the Coastcross-1 had been regularly mowed and fertilized and had never been grazed. A 14 x 6 m area was cut on June 26, 1975, to a height of approximately 8 cm. Upon removal of the cut forage, fertilizer was applied that same day at a rate of 60 kg N, 20 kg P_2O_5 and 40 kg K_2O per ha. Within a 1 meter wide border the area was subdivided in three adjacent rectangular areas of 16 m^2 each, identified by A, B and C. Area A was allowed to grow back for 4 weeks to obtain 4-week-old plant material. From area B 7-week and from area C 12-week-old plant material was obtained after corresponding periods of regrowth. Anonymous (1976) recorded the meterological data for the area in 1975.

Field and Lab Procedure

The macromorphology and quantity of the 4-, 7- and 12-week-old plant material was studied at corresponding time intervals after the cut on June 26, 1976. Not considering the time difference, the difference in age of the plant material and the difference in location, viz. area A, B and C, similar materials and methods were used in these studies. To study the plant material, individual stems were harvested in sample areas of 25 x 20 cm. Twelve sample areas located at randomly selected points were used in each 16 m^2 area. Only the stems originating from below cutting level in a sample area were considered as belonging to the

sample area, this distinction being relevant to lodging stems. The stems were cut at the same height as the previous cut; approximately 8 cm above soil level. The level of the previous cut made on June 26 could be determined in each quadrat from intact stem bases still present.

The description, classification and weight determinations were executed in six separate steps. These steps are schematically sketched in Table 1. Table 1 presents also the type of data obtained in each step. Following is a more detailed account of the six steps.

Step 1. In one corner of each sample area about 20 stems were cut, each stem was described by way of macromorphological measurements after which the stem was discarded. These described and discarded stems together are referred to as stem group 1 to distinguish them from the stems remaining in the sample areas, stem group 2.

Step 2. Based on the information obtained in Step 1, stem classes were defined.

Step 3. The stem class of each stem in stem group 1 was determined from the recorded macromorphological measurements.

Step 4. Cutting and classification of each stem in stem group 2.

Step 5. Macromorphological measurements on those stems of stem group 2, which belong to a stem class of which less than 30 stems have been described.

Step 6. Of stem group 2 the dry matter weight was determined separately for the stems of each stem class within each location. No attempts were made to weigh stems individually, this was only done when of a certain stem class only one stem of stem group 2 happened to be present in a location.

Table 1. Data collection scheme for the study of the macromorphology and quantity of plant material at different ages.

Step	Activity	Data obtained
1	Describe macromorphology of (+) 20 stems in each sample area; these stems designated as stem group 1 are discarded.	A) Number of stems of stem group 1/sample area. B) Macromorphology of (+) 20 stems in 12 sample areas in each of three ages.
2	Definition of stem classes based on description in Step 1.	
3	Classify stems of stem group 1 into stem classes.	C) Number of stems of stem group 1/stem class/ sample area. D) Macromorphology of stems of stem group 1/ stem class/sample area.
4	Classify stems of stem group 2. These are the stems remaining in sample areas after Step 1.	E) Number of stems of stem group 2/sample area. F) Number of stem group 2 stems/stem class/sample area.
5	Describe macromorphology of stems in stem group 3 of those classes where less than 30 stems were described in Step 1.	G) Macromorphology of stems in stem group 2 of some selected stem classes in different sample areas.
6	Weight determination of stem group 2 stems sorted by sample area and by stem class	H) Dry weight of stems of stem group 2/stem class/sample area.

Macromorphology of the Plant Material

The description of individual stems comprised the determination of the following macromorphological characteristics: length; diameter of the top visible internode; diameter of visible internodes at 30, 60 and 90 cm above basal cut on stems where these internodes were present; total number of visible nodes; number of nodes with a visible emerged bud; number of nodes with visible emerged root(s); and number of nodes with three leaves. The definitions of these terms are given in the Glossary.

All data obtained from the individual description of the living stems in stem groups 1 and 3 were used 1) to obtain the range (minimum) and maximum) for each age, 2) to determine the relationships among the macromorphological characteristics within each age, 3) to obtain the mean and range of the macromorphological properties by stem classes and 4) to test the significance of the differences found between the stem classes. The data obtained of the living stems in stem group 1 were used 1) to obtain the means by age and 2) to test the significance of the differences found between the ages.

For the macromorphological characteristics with normally distributed values the SAS programs (Service, 1972) were used to compare the means by age or by stem class and to determine correlations among the macromorphological characteristics.

In some stem classes only a few stems were present and in several locations stems of these stem classes were absent. Stem classes with many such missing values were omitted from the analyses.

For the macromorphological characteristics with a binomial distribution the statistical test used to compare means depended on the particular case. In case the normal distribution provided a reasonably good approximation SAS programs were used. In the other case the Chi-square test was used.

Quantity of the Plant Material

Three response variables were used to quantify the plant material per unit area: the total number of living stems, the total number of nodes and the total dry matter weight of the living stems.

The total number of stems was determined in each of the sample areas, and also the total number of stems of each stem class in each sample area.

Determination of the number of nodes on stems formed a part of the stem description. Of the non-described stems in stem group 2 the number of nodes was estimated. These stems were assigned the mean number of nodes of the described stems of the same class, either in the same sample area or from another randomly selected sample area, in cases such stems were not present in the same sample area.

The dry matter weight was determined of the stems of stem group 2 for each stem class in each sample area. The dry matter weight of the stems of stem group 1 was estimated for each stem class in each location in exactly the same way as described for the estimation of the number of nodes of stem group 2.

Differences among ages and among stem classes were tested with SAS programs (Service, 1972).

Results and Discussion

Macromorphology and Weight of Stems in Plant Materials of Different Age

Macromorphology and weight of living stems within the same plant material differed in one or more, or in all of the macromorphological characteristics measured. Plant material of the same age was made up of a wide variety of stems, ranging from small stems without any visible nodes, i.e., stems without any fully elongated internodes, to stems with several visible nodes or fully elongated internodes. On some of these latter stems nodes with emerged buds and/or roots were present.

Table 2 presents the mean, range and LSD of the macromorphological characteristics and the dry weight of the living stems in plant material sampled after 4, 7 and 12 weeks of regrowth. The minima and maxima of the macromorphological characteristics measured on the stems showed: 1) the wide variability present in the plant material of the same age and 2) the considerable overlap of the range of these characteristics for the different ages. However, for most macromorphological characteristics the means by age were different ($P < 0.05$). Increases from 4 weeks to 7 weeks and subsequently to 12 weeks of regrowth were found in the length ($P < 0.01$), the maximum diameter ($P < 0.05$), the number of nodes ($P < 0.01$) and in the number of nodes with emerged root(s) ($P < 0.01$). From 4 to 7 weeks an increase was found in the diameter measured at the top of the stems ($P < 0.05$), the number of nodes with an emerged bud ($P < 0.01$) and in the number of nodes with three leaves ($P < 0.01$). The weight of the stems showed a large increase from 4 to 7 and subsequently to 12 weeks ($P < 0.01$ and < 0.05).

Table 2. Characteristics of living stems in plant material of different ages.

Age	Parameter	Length	Diameter (cm above cut)					Number of nodes				DM weight
			Top	(30)	(60)	(90)	Max	Total	With			
									Roots	Bud	3 leaves	
weeks		cm	mm					no.				g
4	$\bar{x}$	34.9	1.12				1.12	1.25	0.01	0.02	0.13	0.14
	Min	4.0	0.50				0.50	0.00	0.00	0.00	0.00	
	Max	72.0	2.10				2.10	4.00	3.00	3.00	2.00	
7	$\bar{x}$	68.2	1.24	1.29	1.87		1.28	4.66	0.49	0.33	0.50	0.63
	Min	10.0	0.40	0.60	0.70		0.40	1.00	0.00	0.00	0.00	
	Max	145.0	2.60	2.20	2.40		2.60	9.00	6.00	5.00	4.00	
12	$\bar{x}$	95.2	1.32	1.40	1.64	1.82	1.52	7.75	1.18	0.45	0.46	0.97
	Min	14.0	0.50	0.70	0.70	0.80	0.60	0.00	0.00	0.00	0.00	
	Max	199.0	2.40	2.50	2.50	2.70	2.70	17.00	10.00	7.00	5.00	
	LSD 1%	10.3	0.16	0.13	0.21		0.17	0.59	0.43	0.23	0.24	0.36
	LSD 5%	7.7	0.12	0.09	0.15		0.13	0.44	0.32	0.17	0.18	0.27

Table 3 presents for each of the three regrowth periods the proportion of the stems present in the plant material which had one or more nodes with three leaves and/or emerged root(s) and/or an emerged bud. The percentage of stems with emerged roots and/or emerged bud(s) increased from 4 to 7 and subsequently to 12 weeks ($P < 0.01$ or $P < 0.05$).

Table 3. Percentage of living stems with emerged roots and/or buds and/or three leaves on one node in plant material of different ages.

Plant material age	Stems with		
	Emerged		Three leaves on a node
	Roots	Buds	
weeks	----------%----------		
4	1.1	1.9	12.6
7	23.5	18.6	33.9
12	41.2	28.2	32.8
LSD 1%	13.1	12.1	17.2
LSD 5%	9.7	9.0	12.9

The percentage of stems with one or more nodes with three leaves increased significantly from 4 to 7 weeks ($P < 0.01$) no further changes were observed at 12 weeks. Nodes with three leaves were only encountered at the base of the stem. A node with two leaves was never encountered below a node with three leaves.

The mean values found for the characteristics of the living stems differed with age because 1) most of the stems which stayed alive developed further, 2) with the ageing of the plant material stems were killed by competition and 3) new stems arose from below cutting levels even 4, 7 or 12 weeks after cutting of the sward.

To what degree, differences found can be attributed to (1), (2) or (3) is unknown. However, further development of the stems seems undoubtedly of importance considering the increase with age of the maxima observed for the length, the number of nodes, the number of nodes with three leaves, with emerged roots and with emerged buds. The fact that some stems were killed by competition is also of considerable importance. The initial increase with age of the proportion of stems having a node with three leaves can be attributed probably to a lower death rate of these stems as compared to stems with only two leaves per node. These latter stems were less developed (Table 7) and consequently weaker than the stems having a node with three leaves. For the same reason the increase in stem diameter with age can be attributed at least partly to a higher death rate among thin than among thick stems.

The apparent increase of the stem diameter with height (Table 2) was not observed on individual stems. It resulted from the fact that the diameter at 60 and/or 90 cm could only be measured on stems that were larger overall.

Relationships Between Macromorphological Characteristics

Tables 4, 5 and 6 present the correlation coefficients among the macromorphological characteristics with randomly distributed values. All these characteristics were correlated ($P < 0.0001$) with r varying from 0.20 to 0.98.

Table 4. Correlations among morphological characteristics of stems in 4-week-old plant material.*

	Number of nodes	Diameter at the top
Length	0.74	0.81
Number of nodes		0.44

*r = correlation coefficient, probability $r < r$ under H_o $r = 0$ is < 0.0001 for any r in the table.

Table 5. Correlations among morphological characteristics of stems in 7-week-old plant material.*

	Number of nodes	Diameter (cm above cut)			
		Max.	(30)	(60)	Top
Length	0.89	0.84	0.73	0.81	0.81
Number of nodes		0.71	0.56	0.38	0.67
Maximum diameter			0.92	0.82	0.98
Diameter at 30 cm				0.56	0.89
Diameter at 69 cm					0.79

*r = correlation coefficient, probability $r < r$ under H_o $r = 0$ is < 0.0001 for any r in the table.

Table 6. Correlations among morphological characteristics of stems in 12-week-old plant material.

	Number of nodes	Diameter (cm above cut)					Number of nodes with		
							Emerged		
		Max	(30)	(60)	(90)	Top	Roots	Bud	3 leaves
Length	0.95	0.62	0.65	0.78	0.76	0.43	0.63	0.33	0.51
Number of nodes		0.45	0.55	0.67	0.68	0.24	0.57	0.37	0.47
Maximum diameter			0.92	0.96	0.89	0.87	0.57	0.28	0.50
Diameter at 30 cm				0.84	0.65	0.78	0.53	0.26	0.44
Diameter at 60 cm					0.81	0.82	0.64	0.28	0.47
Diameter at 90 cm						0.81	0.57	0.27	0.45
Diameter at top							0.42	0.20*	0.34
Number of nodes with roots								0.29	0.55
Number of nodes with buds									0.26

*r = correlation coefficient, probability $r < r$ under H_0 $r = 0$ is < 0.001 and < 0.0001 for any other r in table.

Table 7 presents the length, diameter and number of nodes per stem of stems grouped according to the occurrence or not of nodes with three leaves, and/or emerged roots and/or emerged buds. The distribution of the stems in the plant material over these groups is noted in these tables by way of the relative frequency.

A positive relationship between all the macromorphological variables is obvious. Mean values of length, diameter and number of nodes per stem were larger for the stems having one or more nodes with three leaves and/or emerged roots and/or emerged buds than for stems without such nodes. Also, in the 4-week-old material the occurrence of emerged roots or buds on the stems was virtually limited to the stems, which also have at least one node with three leaves. In the 12-week-old stem material the stems with more than four nodes and a diameter of more than 2.1 mm always had one or more nodes with an emerged bud and/or roots (Table 13). Many more similar examples can be seen in Tables 8, 9 and 10.

Stem Classes and Their Characteristics

A classification scheme was set up to form stem classes containing stems with different propagation capacity.

Tables 8, 9 and 10 show the macromorphological limits set for the stem classes in 4-, 7- and 12-week-old plant material, respectively. Stem classes 21 and 41 were created to separate the dead from the living stems in material of 7 and 12 weeks old, respectively.

Tables 11, 12 and 13 present the properties of the living stems belonging to different stem classes distinguished in, respectively, 4-, 7- and 12-week-old plant material. These tables show that most of the

Table 7. Length, diameter, number of nodes and frequency of stems with or without emerged roots, buds and nodes with three leaves in 4-, 7- and 12-week-old plant material.

Presence on stems of nodes with			Length	Maximum diameter	Nodes	Frequency
3 leaves	Emerged					
	Roots	Buds				
			cm	mm	no.	%
			4-week-old plant material			
0*	0*	0*	35	1.1	1.2	87.4
+	0	0	56	1.6	2.2	10.4
0	+	0	--§	---	---	---
0	0	+	--	---	---	---
+	+	0	54	1.4	2.8	0.3
+	0	+	59	1.8	2.3	1.1
0	+	+	59	1.8	4.0	0.0
+	+	+	65	1.9	3.0	0.7
			7-week-old plant material			
0	0	0	57	1.1	4.1	52.5
+	0	0	83	1.5	5.4	14.2
0	+	0	84	1.5	5.6	4.4
0	0	+	61	1.1	4.6	6.6
+	+	0	97	1.7	6.4	9.8
+	0	+	81	1.6	5.9	3.8
0	+	+	90	1.7	6.2	2.7
+	+	+	105	2.0	7.0	6.0
			12-week-old plant material			
0	0	0	68	1.4	5.3	33.9
+	0	0	94	1.6	7.7	11.3
0	+	0	114	1.6	9.5	16.9
0	0	+	82	1.2	7.3	13.0
+	+	0	119	1.6	9.5	9.6
+	0	+	109	1.8	9.1	0.6
0	+	+	114	1.7	10.0	3.4
+	+	+	149	2.1	12.1	11.3

*0 = not present, + = present.

§--No such stems present in the plant material.

Table 8. Defined limits of the stem classes in 4-week-old plant material.

Stem class	Stem length	Nodes on stem	Stem diameter at top	Presence on stem of nodes with		
				3 leaves	Emerged	
					Bud	Root
	cm	no.	mm			
1	[§]	0				
2	≤ 30					
3	> 30	1	< 1.3	0[*]	0[*]	0[*]
4	> 30	1	> 1.3	0	0	0
5	> 30	2	< 1.3	0	0	0
6	> 30	2	> 1.3	0	0	0
7	> 30	2	> 1.3	+	0	0
8	> 30				+	0
9	> 30				0	+
10	> 30				+	+
11	> 30	≥ 3			0	0

[§] Blanks indicate that no limits were defined of the corresponding stem characteristic for the corresponding stem class.

[*] + = present, 0 = not present.

Table 9. Defined limits of the stem classes in 7-week-old plant material.

Stem class	Stem color	Stem length	Maximum stem diameter	Presence on stem of nodes with emerged		Nodes on stem
				Bud	Root	
		cm	mm			no.
21	no green	[§]				
22	green	$\leq$ 30				
23	green	> 30	< 1.3	0[≠]	0[≠]	
24	green	> 30	< 1.3	0+	0+	
25	green	> 30	1.3 - 1.5	0	0	
26	green	> 30	1.3 - 1.5	+	0	
27	green	> 30	1.3 - 1.5	0	+	
28	green	> 30	1.3 - 1.5	+	+	
29	green	> 30	$\geq$ 1.6	0	0	
30	green	> 30	$\geq$ 1.6	+	0	
31	green	> 30	$\geq$ 1.6	0	+	
32	green	> 30	$\geq$ 1.6	+	+	
33	green	> 30	$\geq$ 1.6	0	0	$\leq$ 5

[*]No green = stem and leaves completely brown and yellow, stem has died; green = some parts of stem and/or leaves green, the stem is living.

[§]Blanks indicate that no limits were defined of the corresponding stem characteristic for the corresponding stem class.

[≠]+ = present, 0 = not present, 0+ = presence in at least one of the columns in the row marked 0+.

Table 10. Defined limits of the stem classes in 12-week-old plant material

Stem class	Stem color	Stem length	Maximum stem diameter	Presence on stem of nodes with emerged		Nodes on stem
				Bud	Root	
		cm	mm			no.
41	no green	[§]				
42	green	≤ 30				
43	green	> 30	< 1.3	0[≠]	0[≠]	
44	green	> 30	< 1.3	0+	0+	
45	green	> 30	1.3 - 1.5	0	0	
46	green	> 30	1.3 - 1.5	+	0	
47	green	> 30	1.3 - 1.5	0	+	
48	green	> 30	1.3 - 1.5	+	+	
49	green	> 30	1.6 - 2.1	0	0	
50	green	> 30	1.6 - 2.1	+	0	
51	green	> 30	1.6 - 2.1	0	+	
52	green	> 30	1.6 - 2.1	+	+	
53	green	> 30	≥ 2.2	0	0	
54	green	> 30	≥ 2.2	+	0	
55	green	> 30	≥ 2.2	0	+	
56	green	> 30	≥ 2.2	+	+	
57	green	> 30	≥ 2.2	0	0	≤ 5

*No green = stem and leaves completely brown and yellow, stem has died; green = some parts of stem and/or leaves green, the stem is living.

[§]Blanks indicate that no limits were defined of the corresponding stem characteristic for the corresponding stem class.

[≠]+ = present, 0 = not present, 0+ = presence in at least one of the columns in the row marked 0+.

Table 11. Characteristics of stems of different classes in 4-week-old plant material.

Stem class	Length	Diameter at top	Nodes	Nodes with			Weight (DM)
				Emerged		3 leaves	
				Root	Bud		
	cm	mm	----------%----------				0.01 g
1	16f*	+	0 f	0 b	0 b	0 c	3g
2	24e	0.9f	1.2d	0 b	0 b	0 c	3fg
3	37d	0.9e	1 e	0 b	0 b	0 c	10ef
4	47c	1.5cd	1 e	0 b	0 b	0.1c	19d
5	40d	1.0e	2 c	0 b	0 b	0.1c	13de
6	54b	1.4d	2 c	0 b	0 b	0 c	28c
7	55b	1.6b	2 c	0 b	0 b	1 b	37b
8	59ab	1.8a	2.3b	0 b	1 a	1 b	59a
9	53b	1.4cd	2.8a	1 a	0 b	1.6a	39b
10	64a	1.9a	3.1a	1.7a	1.5a	0.8b	74--
11	60a	1.5bc	3 a	0	0 b	0.9b	40b

*Values not followed by the same letter differ ($P < 0.05$). Values followed by -- were obtained from ≤ 6 observations, they were not included in statistical comparisons.

+Spaces are left open when response variable does not occur.

Table 12. Characteristics of stems of different classes in 7-week-old plant material.

Stem class	Length	Diameter (cm above cut)				Nodes	Nodes with			Weight (DM)
		Top	(30)	(60)	Max		Emerged		3 leaves	
							Root	Bud		
	cm	mm				no.				g
22	20g	0.5g*	+		0.5g	1.8h	0.0e	0.1c	0.0d	0.1e
23	55f	0.9f	1.0e		1.0f	4.0g	0.0e	0.0c	0.1d	0.3de
24	58ef	1.0e	1.0e		1.0f	4.4fg	0.2d	1.1b	0.3d	0.3d
25	75d	1.4d	1.3d	1.4d	1.4e	5.1ef	0.0e	0.0c	0.3d	0.7c
26	71d	1.4d	1.3d		1.4e	5.3ef	0.0e	1.4b	0.6d	0.7c
27	80cd	1.4d	1.3d	1.4d	1.4e	5.5de	1.3c	0.0c	0.9bc	0.5--
28	71de	1.4d	1.3d		1.4e	5.4def	1.0cd	1.4b	0.6d	0.8--
29	94b	1.6c	1.5c	1.6cd	1.7d	6.1cd	0.0e	0.0c	1.0c	1.1b
30	88bc	1.7c	1.6c	1.8bc	1.8cd	6.3bc	0.0e	1.5b	1.5b	1.2b
31	104a	1.7c	1.6c	1.8b	1.8c	6.9ab	2.4b	0.0c	1.5b	1.4--
32	110a	2.0b	1.8b	2.1a	2.1b	7.2a	3.3a	2.0a	2.0a	2.0a
33	54f	2.3a	2.2a		2.3a	2.3h	0.0e	0.0c	0.5d	0.7--

*Values not followed by the same letter differ ($P < 0.05$). Values followed by -- were obtained from $\leq$ 6 observations; they were not included in statistical comparisons.

+Spaces are left open when response variable does not occur.

Table 13. Characteristics of stems of different classes in 12-week-old plant material.

Stem class+	Length	Stem diameter (cm above cut)					Nodes	Nodes with			Weight DM
		Top	(30)	(60)	(90)	Max		Emerged		3 leaves	
								Roots	Bud		
	cm	mm					no.				g
42	20h*	1.3d	§			1.3c	0.7i	0 d	0 c	0 d	0.1e
43	68f	0.9e	1.0d	1.1--	0.8--	1.0d	6.3g	0 d	0 c	0.13cd	0.4de
44	71f	0.9e	1.0d	1.0--		1.0d	6.6fg	0.4c	1.0b	0.14cd	0.4de
45	91e	1.2d	1.3c	1.3c	1.4--	1.4c	7.6ef	0 d	0 c	0.20cd	0.7cd
46	93de	1.2d	1.3c	1.2c	1.3--	1.4c	8.2de	0 d	1.7ab	0.08d	0.7c
47	102de	1.2d	1.3c	1.3c	1.3--	1.4c	8.8cde	1.7b	0 c	0.58bc	1.0--
48	103de	1.2d	0.4--	1.4--	1.3--	1.4c	9.3bcd	1.4bc	2.0ab	0.33bcd	0.9--
49	120bc	1.5c	1.6b	1.6b	1.6b	1.7b	9.9bc	0 d	0 c	0.43bcd	1.3b
50	110cd	1.6bc	1.5--	1.7--	1.7--	1.7b	8.9bcde	0 d	1.4b	1.00b	1.3--
51	131b	1.6bc	1.6b	1.7b	1.7b	1.8b	10.4b	2.6b	0 c	0.52bc	1.5b
52	129b	1.6c	1.6b	1.7b	1.7b	1.8b	10.8b	2.7b	2.2a	0.71b	1.6b
54	85--	2.3--	2.3--	2.3--		2.3--	6.0--	0 d	1.3--	1.30--	1.7--
55	150a	1.8abc	1.9--	2.3--	2.0--	2.3a	11.2a	4.6a	0 c	1.00b	2.2--
56	159a	1.8a	1.9a	2.3a	2.2a--	2.3a	12.7--	4.8a	2.4a	1.93a	3.6a
57	54g	1.8ab	1.9--			1.8b	2.7h	0 d	0 c	0.19cd	0.4cde

*Stem class 53 is not listed as no stems occurred in that class.

*Values in the same column not followed by the same letter differ ($P < 0.05$) according to Duncan's multiple range test. Values followed by -- are obtained from ≤ 6 observations; they were not included in statistical comparisons.

§Spaces are left open when response variable does not occur.

stem classes also differed ($P < 0.05$) in other than the defined limits. For example, in the 4-week-old plant material stems of classes 8, 9 and 10 were distinguished from classes 3 through 7 by having emerged buds and/or roots. They were also found to differ ($P < 0.05$) in the number of nodes. In the 7-week-old plant material stems of stem class 32 were distinguished from stem class 30 by the presence of emerged roots. They were also found to differ ($P < 0.05$) in length, maximum diameter, number of nodes, number of nodes with buds and number of nodes with three leaves. In the 12-week-old plant material stems of stem class 56 were distinguished from stem class 52 by difference in maximum diameter. They were also found to differ ($P < 0.05$) in length, number of nodes, number of nodes with buds, roots and three leaves.

In the 7- and 12-week-old material several of the stem classes, with the same diameter criteria, did not differ at the $P < 0.05$ level in other characteristics than their defined class characteristics. This was the case for stem classes 23 and 24; 25 through 28; 45 through 48; and 49 through 52. In general, however, the stem classes subdivided the stems also different in other morphological characteristics than the ones used to define the stem classes.

In addition to macromorphological characteristics, Tables 11, 12 and 13 present the mean weight of the stems of each stem class. In this respect the stems of many stem classes were also different ($P < 0.05$).

Plant Material Quantity and Distribution over Stem Classes

Table 14 presents the number of living stems, their weight and the total number of nodes per m^2 in plant material of 4, 7 and 12 weeks old from which dead stems have been removed. Each of these response

Table 14. The quantity of plant material after different regrowth periods.

Age	Stems	Weight (DM)	Nodes
weeks	no./m^2	kg/m^2	no./m^2
4	1910	0.27	2500
7*	760	0.48	3500
12*	610	0.59	4500
LSD 1%	270	0.20	1300
LSD 5%	200	0.15	900

*Stem classes 21 and 41 with dead stems not included.

variables was used as a measure of the quantity of plant material which was harvested from one m^2. The figures show that the number of nodes per m^2 increased ($P < 0.05$) with the ageing of the plant material, whereas the total number of (living) stems decreased ($P < 0.01$) by more than 50% from 4 to 7 weeks of regrowth, the observed decrease from 7 to 12 weeks was not significant. The weight of the plant material increased ($P < 0.01$) from 4 to 7 weeks by roughly 80%; the increase from 7 to 12 weeks was approximately 20% ($P < 0.05$).

Tables 15, 16 and 17 present the quantity of plant material as distributed over the stem classes in 4-, 7- and 12-week-old plant material, respectively.

Stem classes 1 through 7, characterized by having two or less nodes per stem, accounted for 95% of the stems, 84% of the weight and 90% of the nodes of the 4-week-old plant material.

Table 15. The macromorphological composition of 4-week-old plant material in terms of its distribution over stem classes.

Stem class	Stems	Weight (DM)	Nodes
	----------%----------		
1	15b*	3d	0g
2	21a	6cd	19b
3	18ab	13b	13c
4	7c	10bc	6ef
5	21a	20a	32a
6	5cd	11bc	8de
7	8c	21a	12cd
8	1e	5d	2fg
9	1e	3d	2fg
10	1e	3--	1fg
11	2de	6cd	4efg

*Values in the same column not followed by the same letter differ ($P < 0.05$).

In the 7-week-old material, 34% of the stems harvested with the plant material were dead and fell in stem class 21. The (living) plant material was dominated by two groups of stem classes: stem class 23 and 25 containing stems with a diameter of less than 1.6 mm and no emerged roots or buds; and stem class 29 through 32 containing stems with a diameter of 1.6 mm or larger, the majority of these stems had emerged root(s) and/or bud(s). Stem class 23 and 25 accounted for 50% of the stems, 34% of the weight and 51% of the nodes of the plant material. Stem class 29 through 32 accounted for 19% of the stems, 52% of the weight and 31% of the nodes.

In the 12-week-old material, 33% of the stems harvested with the plant material were dead and belonged to stem class 41. The remainder

Table 16. The macromorphological composition of 7-week-old plant material in terms of its distribution over stem classes.

Stem class	Stems	Weight (DM)	Nodes
	----------%----------		
21	34a*	7bcd	--+
22	4d	1d	3cd
23	25b	15ab	30a
24	4d	3cd	6cd
25	12c	17a	21b
26	3d	5cd	5cd
27	2d	2--	3cd
28	1d	1--	1d
29	3d	8bcd	7cd
30	3d	9bc	7cd
31	4d	12--	7cd
32	4d	20a	10c
33	1d	1--	0--

*Values in the same column not followed by the same letter differ ($P < 0.05$). Values followed by -- were obtained from ≤ 6 observations. They were not included in the analyses.

+Nodes on dead stems were not included.

Table 17. The macromorphological composition of 12-week-old plant material in terms of its distribution over stem classes.

Stem class	Stems	Weight (DM)	Nodes
	----------%----------		
41	33a*	6cd	--+
42	4cdef	1d	1d
43	8bc	4cd	10b
44	6bcde	3d	8c
45	11b	10bc	17a
46	5cdef	5cd	5cd
47	4cdef	5--	7cd
48	2def	2--	4cd
49	3cdef	4cd	6cd
50	2ef	3--	3cd
51	7bcd	16b	15ab
52	4cdef	9bcd	9bc
53	0--	0--	0--
54	0f	1--	1--
55	1f	2--	2--
56	5cdef	26a	12ab
57	5cdef	3cd	2cd

*Values in the same column not followed by the same letter differ ($P < 0.05$). Values followed by -- were obtained from ≤ 6 observations. They were not included in the analyses.

+Nodes on dead stems were not included.

of the material is dominated by stem class 43 and 45 containing stems with a diameter of less than 1.6 mm and no emerged roots or buds; stem class 51 and 52 containing stems ranging in diameter from 1.6 through 2.1 mm with emerged root(s) and with or without emerged bud(s); and stem class 56 containing stems with a diameter of 2.2 mm or larger with both emerged roots and buds.

CHAPTER 4
MACROMORPHOLOGY AND PROPAGATING CAPACITY

Introduction

Van Dillewijn (1952) reported that sugarcane cuttings of one node were stronger when the axillary bud had emerged. He also reported that different sections of a cane stalk differed in percentage of bud emergence, speed of bud germination and of root emergence. Differences in propagating capacity between propagules of the same plant material are not reported in the literature on forage grasses.

The objectives of this study were

1. To determine for the grass Coastcross-1 the difference in propagating capacity between propagules of

   a. Stems different in macromorphology and

   b. Different sections of stems with the same macromorphology.

2. To determine these differences in propagating capacity both under optimal soil-moisture conditions and under conditions of soil moisture deficiency.

Materials and Methods

Comparing the Propagating Capacity

The propagules for this study were obtained from the same area described in Chapter 3. Propagules of 4-, 7- and 12-week-old plant material were studied at corresponding time intervals after the area

was staged by cutting on June 26, 1976. In each of these three different studies four different propagule types were compared. Propagules of the same type were obtained from similar sections of stems of the same stem class. Five propagules of the same type were planted in a single pot. Five pots of each propagule type were subjected to intervals of moisture stress and five pots to an optimum moisture regime. A complete factrial experiment was executed in each study (4 propagule types x 2 moisture regimes with 5 pots per treatment and 5 propagules nested in each pot).

The propagules stayed in the pots over a period of 14 days. During this period observations were made on the development of above ground parts (Tables A-7 through A-12). At the end of the 14 days the pots were submerged and the propagules were gently freed from the soil. A description of top growth, axillary buds and roots was made and the dry weight of these parts was determined (Tables 19, 20, 21 and A-7 through A-12). These responses were used to compare the propagating capacity of the different propagules. Wtih the description and weight determination of the roots, no distinction was made between cutting and shoot roots. The shoot roots accounted for less than 1% of the total root mass at the end of the 14-day growth period. On some nodes two buds were observed. The youngest of these buds had never emerged and had probably not developed much since planting. These puds were omitted from the description and weight determination.

Propagule Types

The propagules were cut from stems of specific stem classes, the characteristics of which were described in Chapter 3. The main

distinctive characteristics of the propagule types studied are listed in Table 6. Of each propagule type, 60 propagules were prepared at the time of planting. Fifty of these propagules were planted in pots. Ten propagules were described before planting (Tables 18 and A-1 through A-6). Of propagule types 8 and 25C, less propagules were available and, respectively, 8 and 9 pots were planted and of type 8 only one propagule was described before planting.

Almost complete stems were used as propagules of the 4-week-old plant material; none of the nodes present on the harvested stems were removed. Propagule type 3 which contained only one node was cut 7.5 cm below and 15 cm above this node. All other propagule types were cut 2.5 cm below the basal node and 2.5 cm above the top node. Of propagule types which contained the stem apex, the top leaves were cut at the level of the base of the leafblade on the third leaf above the top visible node. Leaves originating from lower nodes were cut 2.5 cm above the leaf sheath when the leaves were green.

Soil Moisture Regimes

Steamed top soil of an Arredondo loamy fine sand was put in pots and packed to a density of 1.4 g dry soil/cm^3. At this density the total pore space of the soil was 40%. The moisture release curve of the soil at this density was determined. At a soil moisture tension of a) - 100 cm H_2O the soil contained 14.7% H_2O by volume or 10.5% H_2O by weight and b) -15 bar the soil contained 6.3% H_2O by volume or 4.5% by weight. Preliminary tests indicated that a close to optimal moisture regime for propagules of young plant material was obtained by a wetting and drying cycle of the pot soil from -100 cm to -15 bar. This was

Table 18. Main distinctive characteristics of propagule types studied.

Propagule type		Propagule contains				Stem diameter
				Emerged		
Stem class	Section	Visible nodes	Apex	Bud	Roots	
		no.				mm
		4-week-old plant material				
3		1	+[§]	0[§]	0[§]	< 1.3
5		2	+	0	0	< 1.3
7		2	+	0	0	> 1.3
8		2	+	+	0	> 1.3
		7-week-old plant material				
22	C[*]	3	0	0	0	< 1.3
25	C	3	0	0	0	1.3 - 1.5
25	A	3	+	0	0	1.3 - 1.5
32	A	3	+	0	0	≥ 1.6
		12-week-old plant material				
45	B	3	0	0	0	1.3 - 1.5
45	C	3	0	0	0	1.3 - 1.5
47	B	3	0	0	+	1.3 - 1.5
51	B	3	0	0	+	1.6 - 2.1

[*] C = center part of stem, B = base part of stem.

[§] + = present, 0 = not present.

chosen as the optimal moisture regime in all three studies. The same preliminary tests indicated that when the soil was rewetted 24 hours after the soil moisture tension had fallen to -15 bar, the propagules were performing very poorly. The propagules of the 4-week-old material were subjected only for 12 hours to soil moisture tensions below -15 bar. Thus, 12 hours after the soil moisture tension had been reduced by evaporation to -15 bar, the soil was rewetted to -100 cm H_2O. A similar procedure was followed with the 7- and 12-week-old material with the exception that the propagules under the dry moisture regime were subjected to a period of 24 and 48 hours, respectively, of soil moisture tension below -15 bar. The changes in moisture tensions were checked by weighing the pots. In general, after rewetting to -100 cm H_2O the soil moisture was reduced to -15 bar in 2 days. Depending on greenhouse conditions, this interval was observed to have an extreme variation of 25 to 66 hours.

Planting of the Pots

Soil analyses showed that the plant nutrient status of the soil was satisfactory, and therefore no fertilizer was applied. To accomodate the long propagules an aluminum loaf pan of the following dimensions was used as a pot: height, 5.2 cm; bottom area, 18.8 x 8.4 cm; top area, 20.2 x 10.4 cm; and a volume of 1 liter.

The propagules were planted with a slight upward angle from the horizontal. The basal two nodes were placed approximately 1 cm below the soil surface. The apex and/or the third node were above the soil surface. The propagules were planted parallel to the long side of the pot at equal spacings with the tips alternately pointing in different directions.

Statistical Analyses

The responses expressed as percentages were transformed to arcsin. Statistical analyses were performed on the arcsin values using the SAS programs (Service, 1972). The other responses, e.g., root and bud weight, were found to have unequal variances in the different treatments. The treatment means were compared with Wilcoxon's ranking test (Verdooren, 1963).

Results and Discussion

The development of the propagules over the 14-day growth period is summarized in Tables 19, 20 and 21. A more detailed account is given in Tables A-7 through A-12.

Four-Week-Old Plant Material

Propagule type 3 under optimum and dry moisture regimes and type 5 under the dry moisture regime showed greater death losses ($P < 0.05$) than types 7 and 8 under the dry moisture regime. The propagating capacity of types 7 and 8 was superior to types 3 and 5. The percentage of dead propagules of type 5 was lower than that of type 3 under the same growing conditions ($P < 0.05$). This indicated that the propagating capacity of type 5 was slightly superior to type 3, even though no other differences were observed. The apex growth, the weight of buds and roots of type 8 under dry or optimum soil moisture conditions exceeded those of type 7 under optimum moisture conditions. The propagating capacity of type 8 was thus superior to type 7. The propagule types can be ordered with regard to their propagating capacity as $3 < 5 <<< 7 << 8$.

Table 19. Propagule development 14 days after planting of four propagule types found in 4-week-old plant material.

Propagule type	Moisture regime	Dead propagules	Apex growth	Bud weight	Root		
					Emergence	Number	Weight
		%	mg	mg	%	no.	mg
3	Dry	76a[§]	0.09a	0.1a	0a	0 a	0 a
	Optimum	44ab	0.02a	0.2ab	18a	0.3a	0.3b
5	Dry	34b	0.02a	0.4ab	4a	0 a	0.1a
	Optimum	14c	1.02a	0.5b	18a	0.3a	0.8ab
7	Dry	18c	18.13b	2.3c	76b	1.8b	5.1c
	Optimum	6c	22.96b	4.3c	92bc	2.3b	6.2c
8	Dry	10c	40.14c	37.7d	88bc	3.8bc	23.0d
	Optimum	0c	55.91c	48.0d	100c	4.2b	21.5d

[§]Values in the same column not followed by the same letter differ ($P < 0.05$).

Table 20. Propagule development 14 days after planting of four propagule types found in 7-week-old plant material.

Propagule type	Moisture regime	Dead propagules	Apex growth	Bud weight	Apex & bud	Root		
						Emergence	Number	Weight
		%	mg	mg	mg	%	no.	mg
23C	Dry	12a[§]		1.6a	1.6a	22a	0.4ab	0.1a
	Optimum	2a		7.4c	7.4c	64b	0.9ab	1.7ab
25C	Dry	0a		5.0b	5.0b	56ab	1.0bc	1.2ab
	Optimum	0a		12.7d	12.7de	78b	1.8bc	1.8b
25A	Dry	0a	0.6a	1.5a	2.1a	16a	0.2a	0.5a
	Optimum	2a	8.1b	2.1a	10.1cd	70b	1.9cd	6.9c
32A	Dry	0a	11.2bc	5.4bc	16.6ef	59ab	1.8c	10.2c
	Optimum	0a	18.1c	4.6b	22.7f	85b	2.5d	8.6c

[§]Values in the same column not followed by the same letter differ ($P < 0.05$).

Table 21. Propagule development 14 days after planting of four propagule types found in 12-week-old plant material.

Propagule type	Moisture regime	Dead propagules	Bud weight	Root		
				Emergence	Number	Weight
		%	mg	%	no.	mg
45B	Dry	26a[§]	3.3a	46a	0.7ab	0.4ab
	Optimum	4b	7.1bc	52a	0.7a	0.3a
45C	Dry	4b	4.6ab	60ab	0.8ab	0.5b
	Optimum	0b	8.0c	64abc	1.0b	0.6b
47B	Dry	4b	7.2c	82bc	1.7c	0.9bc
	Optimum	2b	11.3d	78bc	2.2cd	2.1c
51B	Dry	0b	11.9d	86c	2.4d	2.0c
	Optimum	0b	18.2e	86c	3.2d	2.8c

[§]Values in the same column not followed by the same letter differ ($P < 0.05$).

Relating this to the macromorphological differences between the stem classes from which these propagules were derived it can be concluded that in the 4-week-old plant material a) among stems with a diameter smaller than 1.3 mm those with two nodes had a better propagating capacity than the stems with one node and b) the stems with two nodes, i.e., stem classes 5, 7 and 8, all differ in more than one morphological characteristic. The following combinations of morphological characteristics caused the differences in propagating capacity: stems with a diameter smaller than 1.3 mm and nodes with only two leaves (class 5) were inferior to stems with a diameter larger than 1.2 mm and one or more nodes with three leaves (class 7), which in turn were inferior to stems with an emerged bud and a diameter larger than those of the other stems (class 8).

Seven-Week-Old Plant Material

When propagule types were grown under the same conditions no differences ($P < 0.05$) were observed in percentage of dead propagules nor in percentage of propagules with emerged roots. However, in the other responses, differences occurred between some propagule types. Under optimum moisture conditions 25A was superior to 23C ($P < 0.05$) with respect to root weight and number of roots. Under dry conditions 23C and 25A did not differ. Thus, depending on moisture conditions the propagating capacity of 25A was slightly better or equal to 23C. Grown under the same moisture conditions, the weight of the buds of 25C exceeded that of 23C ($P < 0.05$). No other differences between these two types were found. The differences ($P < 0.05$) between 25C and 25A were a) under the dry moisture regime 25C surpassed 25A both in weight of apex & buds

and in root number and b) under the optimum soil moisture regime 25A surpassed 25C in root weight.

Propagule type 32A was superior to all other types under both dry and optimum moisture conditions with respect to apex growth, weight of apex & buds, number of roots and weight of roots. The propagule types can be ordered with regard to their propagating capacity a) under the dry soil moisture regime as 23C = 25A < 25C <<< 32A and b) under the optimum soil moisture regime as 23C < 25C < 25A << 32A.

Relating this to the stem sections and the macromorphology of the stem classes from which these propagules were derived, it can be concluded that in the 7-week-old plant material among stems of class 25, the top section provided better propagules than the center section for optimum moisture conditions. However, these top section propagules were inferior under dry conditions. The top section propagules were more drought sensitive than the center section. On the other hand, the top section of class 32 stems was much less adversely affected by the dry conditions. Thus, the drought sensitivity of the top section depended on the macromorphology of the stem. The fact that propagule 25A was equal or superior to 23C indicated that, among the propagule types studied, differences in propagating capacity related to stem class and macromorphology outweighed those related to stem section. The superior propagation of 25C compared to 23C and of 32A compared to 25A indicated that the propagating capacity increases with increasing stem diameter.

Twelve-Week-Old Plant Material

Propagule types 45C and 45B were different ($P < 0.05$) only in the following respects: a) under the dry moisture regime more propagules

of 45B died and b) under the wet moisture regime 45C surpassed 45B in root number and weight of roots. Thus, under both moisture regimes the propagating capacity of 45C was superior to 45B.

Under a dry or optimum moisture regime 47B was superior to 45C in weight of buds. Under the optimum moisture regime 47B was further superior to 45C in root number and weight of roots.

The differences between 51B and 47B were the larger weight of the buds of 51B than of 47B under equal moisture conditions and the larger number of roots under dry moisture conditions. Summarizing, the propagules can be ranked with regard to their propagating capacity as $45B < 45C < 47B << 51B$.

This sequence indicates that in the 12-week-old plant material a) among stems of stem class 45 the center section provided better plant material than the basal section, b) among stems with a diameter between 1.3 and 1.5 mm the base sections of stems with emerged roots were superior to the basal and center sections of stems without emerged roots, c) among the stems with emerged roots the propagating capacity increased with increasing stem diameter and d) the differences found in propagating capacity between stem classes outweighed the differences between stem sections.

CHAPTER 5
ETHREL EFFECTS ON PROPAGATING CAPACITY

Introduction

The preliminary tests discussed in Appendix B showed that growth regulator treatments sometimes improved the rooting of plant material of several tropical grasses including Coastcross-1. In the cases where the growth regulator treatments improved rooting, the bud growth was generally not affected or slightly improved. The following growth regulator treatments were successful in one or more tests: a) a one minute dip of the plant material in an aqueous solution of Ethrel ranging from 100 to 3000 ppm in concentration, b) two to four day enclosure of propagules before planting in water saturated air containing ethylene at concentrations ranging from 5 to 1000 ppm and c) a one minute dip in 100 to 300 ppm IBA solutions.

The IBA suppressed bud growth in the first days after planting. The following studies on the effect of Ethrel treatment of propagules were done with the objectives:

1. To obtain decisive information on the benefits of Ethrel treatment of plant material as harvested by farmers.
2. To determine the limit beyond which Ethrel has adverse effects.
3. To determine the effect of Ethrel on the emergence and growth both of roots and of buds.

Materials and Methods

Plant Material, Ethrel Treatment and Lay-Out

The effect of Ethrel was studied with 4-, 7- and 12-week-old plant material harvested from areas A, B and C (see Chapter 3), respectively. When the material was cut, care was taken to keep the bases of the stems together. Going upward from the stem base, approximately 25 cm long sections were cut from the plant material. Of the 4-week-old material only the propagules of the base section were studied. Of the 7- and 12-week old material the propagules of the base section and the next section above which is referred to as the center section were studied. The propagules of the same section were mixed thoroughly and in the case of the 4- and 7-week-old plant material some very limited sorting was done whereby most propagules without visible nodes and dead propagules were removed. The 12-week-old material was more carefully sorted. After sorting, the propagules to be treated with Ethrel were submerged for one minute in a solution of Ethrel in distilled water. The propagules not to be treated with Ethrel were not submerged. In the study of the 4- and 7-week-old plant material Ethrel solutions of 100, 1000 and 10,000 ppm were used. The 12-week-old material was treated with 30, 300 and 3000 ppm solutions. The propagules were lightly shaken to remove most of the excess solution after submergence. For each age of plant material, two batches of treated propagules were tested separately: one batch under intermittent mist, the other under prevailing field conditions.

The test with 4-week-old material was replicated six times, the tests with the 7- and 12-week-old material were replicated four times.

Each replication contained 50 propagules. In all tests a completely randomized design was used.

It was not possible to avoid confounding the age of the plant material with the prevailing environmental conditions upon planting because the plant materials of different age were harvested and planted at different dates. Thus, the effects of the factors age and prevailing environmental conditions could not be separately analyzed.

Studies under Intermittent Mist

A 50% light transmitting Saran screen was erected outside at 50 cm above the soil surface, and a timer-controlled mist spray system set up beneath the screen. Prior to planting, the sandy soil was clean cultivated. The propagules were laid down on the soil surface parallel to each other, spaced about 1 cm apart.

The 4- and 12-week-old material was harvested after 14 days under the mist system; the 7-week-old material after 8 days. With the mist system turned on from 07.00 to 22.00 hours giving 2.5 seconds of mist every 3.3 minutes, the propagules stayed covered with a film of water through the day. This mist cycle was used uninterrupted for the 4- and 7-week-old material. With the 12-week-old material it was interrupted from day 5 through day 8 after planting when the propagules were thoroughly wetted only at 11.00, 15.00 and 19.00 hours, thus subjecting the propagules to some moisture stress. The responses measured are listed with the results in Tables 22, 23, and 24.

Studies under Field Conditions

The propagules were planted in a Arredondo fine loamy sand. The soil was rototilled prior to planting. Soil analyses indicated a medium to high P and K status, therefore no fertilizer was applied. By pressing a bamboo stick of 1 cm diameter into the soil 15 cm deep holes were made. These holes were spaced at 30 cm in a rectangular grid and in each hole one propagule was planted. The holes were closed by pressing the soil firmly around the planted propagules. In the case of the 4-week-old plant material the propagules were harvested, treated and planted on the same day. In the case of the 7- and 12-week-old material the propagules stayed overnight after being harvested and treated as the soil was so dry in the afternoons that the holes collapsed after withdrawal of the planting stick. The propagules were planted the next day; in the case of the 7-week-old material the soil was irrigated before planting, whereas with the 12-week-old material a light shower and dew had wetted the soil sufficiently. The responses measured are listed with the results in Tables 25, 26 and 27.

For yield determination, only living propagules were harvested. They were dug up from the soil to include every part of the buds originating below the soil level. No efforts were made to harvest all of the roots.

Some rain fell on the days that the 4-, 7- and 12-week-old material was planted. The 4-week-old material was not exposed to extreme dry conditions during the first 2 weeks after planting. After that a 14-day period with 12 dry days occurred.

After the day of planting the 7-week-old material, a 9 day period followed in which 3 mm of rain fell. Consequently, this material was exposed to very dry conditions. After that the precipitation seemed sufficient for plant growth.

The 12-week-old material was not subjected to very dry conditions, but in several nights minimum night temperatures below 14°C were recorded.

Statistical Analyses

The results for the 4-, 7- and 12-week-old plant material were analyzed separately. The arcsin transformation was used for the responses which were expressed as percentages. Statistical analyses were performed on the arcsin values.

The effect of section of plant material and the interaction of section x Ethrel were determined by analysis of variance. Regression analysis was used to determine the effects of different Ethrel levels. Quadratic curves were fitted using the $^{10}\log$ transformation of the Ethrel concentration in ppm. When the linear and/or quadratic component was significant, all concentrations differed in their effects ($P < 0.05$) (Chew, 1976).

Results and Discussion

Studies under Mist

The effects of Ethrel treatments upon the percentage of propagules with emerged buds, propagules with emerged roots and dry weight both of emerged buds and emerged roots are presented in Tables 22, 23 and 24 for 4-, 7- and 12-week-old plant material, respectively.

Table 22. Effect of Ethrel treatment on emergence and development of 4-week-old plant material under mist.

Ethrel	Propagules with emerged						Dry weight on day 14			
	Buds on day			Roots on day			Planted propagules		Propagule with emergence	
	4	8	14	4	8	14	Buds[+]	Roots[+]	Buds[+]	Roots[+]
ppm	----------%----------						----------%----------			
0	7	66[§]	92[§]	18	51[§]	89[§]	17.2	6.7	18.6	7.5
10^2	6	79	98	15	69	96				
10^3	6	83	97	20	75	97	16.9	8.4	17.5	8.7
10^4	6	87	97	16	75	95				

[+]Only emerged buds and roots.

[§]Ethrel concentrations differ in their effects (P 0.05).

Table 23. Effect of Ethrel treatment on emergence and development of 7-week-old plant material under mist.

Plant material section	Ethrel	Propagules with emerged				Dry weight on day 8			
		Buds on day		Roots on day		Planted propagule		Propagule with emergence	
		4	8	4	8	Buds[+]	Roots[+]	Buds[+]	Roots[+]
	ppm	----------%----------				----------mg/propagule----------			
Base	0	28[*§]	65[*]	36[*]	56[*§]	3.15[*]	0.45[*§]	4.86[*]	0.89[*§]
	10^2	34	65	38	59				
	10^3	29	64	42	57	4.24	1.80	6.69	3.12
	10^4	17	54	26	47				
Center	0	31[§]	83	67	82	10.43	2.68[§]	12.47	3.27[§]
	10^2	64	88	75	86				
	10^3	53	91	82	90	11.41	6.13	12.61	6.85
	10^4	20	90	42	89				

[+]Only emerged buds and roots.

[*]Sections differ ($P < 0.05$).

[§]Ethrel concentrations differ in their effects within corresponding section ($P < 0.05$).

Table 24. Effect of Ethrel treatment on emergence and development of 12-week-old plant material under mist.

Plant material section	Ethrel	Propagules with emerged						Dry weight on day 14			
		Buds on day			Roots on day			Planted propagules		Propagule with emergence	
		4	8	14	4	8	14	Buds[+]	Roots[+]	Buds[+]	Roots[+]
	ppm	----------%----------						----------mg/propagule----------			
Base	0	12[§]	15[*]	51[*]	16[≠§]	16[*]	35[*]	3.45[*]	4.71[*§]	7.00[§]	13.5[§]
	3 x 10	4	17	52	3	11	34				
	3 x 10^2	5	20	48	4	18	35	2.50	8.01	5.18	23.0
	3 x 10^3	4	19	53	7	13	42	2.55	5.96	4.90	14.5
Center	0	9[§]	27	74	7	22	74	6.45	8.46[§]	8.70	11.4[§]
	3 x 10	7	23	74	14	29	63				
	3 x 10^2	4	24	75	12	33	73	5.75	14.32	7.62	19.3
	3 x 10^3	2	26	70	7	29	67				

[+]Only emerged buds and roots.

[§]Ethrel concentrations differ in their effects within corresponding section ($P < 0.05$).

[*]Sections differ ($P < 0.05$).

[≠]Interaction Section * Ethrel ($P < 0.05$).

Weight of the emerged roots per planted propagule

In each of the five plant materials the root weight of the best Ethrel treatment exceeded that of the control ($P < 0.05$) for four of the five plant materials.

Weight of the emerged roots per propagule with emerged roots

In the five plant materials tested the root weight of the best Ethrel treatment exceeded that of the control ($P < 0.05$ in the cases of 7- and 12-week-old plant material).

Propagules with emerged roots

The Ethrel response was not consistent among the different plant materials. In the 4- and 7-week-old plant material the 100 and 1000 ppm Ethrel increased the percentage of propagules with emerged roots ($P < 0.05$ in five out of seven occasions) or did not result in a change. The Ethrel affected the percentage of the 12-week-old material only on day 4, namely an increase for the center and a decrease for the base section ($P < 0.05$). For all plant materials the highest Ethrel level tested, i.e., 3000 or 10,000 ppm, was beyond the optimum; positive, zero and negative responses were observed at the highest Ethrel level.

Weight of emerged buds per planted propagule

In all the five plant materials the bud weight of the best Ethrel treatment did not differ from the control.

Weight of emerged buds per propagule with emerged buds

In the 4- and 7-week-old material the bud weight of the best Ethrel treatment did not differ from the control. In both sections of the 12-week-old plant material the bud weight of the best Ethrel treatment was lower than that of the control. The data in Table 24 show that in a proportion of the 12-week-old material, bud emergence was initially retarded by Ethrel. Apparently, the bud development, reflected by the bud weight, was also retarded by the Ethrel.

Propagules with emerged buds

The Ethrel response was not consistent among the different plant materials. In the 4- and 7-week-old material the 100 and 1000 ppm Ethrel increased the percentage ($P < 0.05$ in four out of seven occasions) or did not cause a change. The Ethrel initially decreased the percentage in the 12-week-old materials ($P < 0.05$). For all plant materials 3000 or 10,000 ppm was beyond the optimum level. In all cases the effects of Ethrel on the emergence seemed to be of a temporary nature.

Main findings

In short the following results were obtained in the tests under mist:

Ethrel at levels of 300, 1000 and 3000 ppm increased the weight of the emerged roots by 20 to 390%. This increase was mainly due to the increased total root weight on propagules with roots, rather than due to an increase in the number of propagules with emerged buds. Ethrel at

these levels had no effect on the weight of the emerged buds. Four days after planting an effect of these three Ethrel levels on root and bud emergence was noticeable, it had disappeared by the 8th or 14th day after planting. This short-term effect was positive with the 4- and 7-week-old material and negative with the 12-week-old material.

The highest Ethrel levels tested, 3000 or 10,000 ppm. were beyond optimum. At these levels Ethrel had some minor adverse effects on some of the plant materials. The data indicated a wide safety range for Ethrel.

Studied under Field Conditions

Tables 25, 26 and 27 show for the sections of 4-, 7- and 12-week-old plant material, respectively, the responses to the different Ethrel treatments.

Weight per planted propagule

Forty-two days after planting, propagules treated with 30 or 100 ppm Ethrel were higher in weight than controls ($P < 0.05$). In four out of the five plant materials, treatment with 3000 or 10,000 ppm Ethrel reduced the weight ($P < 0.05$). These Ethrel levels were too high. The weight was increased by the intermediate Ethrel concentrations in the case of the 7-week-old materials and the base section of the 12-week-old material ($P < 0.05$) and decreased in the case of the 4-week-old material and of the center section of the 12-week-old material ($P < 0.50$).

Fitted quadratic regression equations indicated optimum Ethrel concentrations ranging from 10 to 100 ppm for the different plant materials planted at different dates. Fifty ppm Ethrel is indicated as optimum by

Table 25. Effect of Ethrel treatment on emergence and development of 4-week-old plant material under field conditions.

Ethrel	Growing propagules on day			Propagules with visible emerged buds situated						Dry weight on day 42	
				Above soil			Below soil				
	8	14	42	8	14	42	8	14	42	Planted propagules	Living propagules
ppm	----------%----------									-------g/propagule------	
0	12	25	29	8	16	27	1	3	12	0.72[§]	2.52[§]
10^2	10	24	29	7	16	24	2	3	12	0.75	2.57
10^3	10	26	31	8	17	29	1	6	14	0.57	1.86
10^4	9	17	20	7	10	17	2	5	10	0.28	1.39

[§]Ethrel concentrations differ in their effects (P 0.05).

Table 26. Effect of Ethrel treatment on emergence and development of 7-week-old plant material under field conditions.

Plant material section	Ethrel	Growing propagules on day			Propagules with visible emerged buds situated						Dry weight on day 42	
					Above soil on day			Below soil on day				
		8	14	42	8	14	42	8	14	42	Planted propagules	Living propagules
	ppm	----------			----------			%	----------		-------	g/propagule ------
Base	0	16*§	21*§	19*§	15*§	19*§	18*	0	2*§	12*	0.34*§	1.77*§
	10^2	21	28	26	18	23	24	1	5	17	0.42	1.61
	10^3	15	21	20	15	20	20	1	2	15	0.48	2.63
	10^4	6	9	8	6	8	8	0	1	7	0.06	0.74
Center	0	23§	40	49	21§	39	49	1	1	34	0.88§	1.79§
	10^2	38	48	50	32	47	48	1	1	42	1.21	2.35
	10^3	43	54	56	38	52	54	1	0	47	1.47	2.69
	10^4	42	48	47	34	46	45	2	2	36	1.02	2.14

*Sections differ ($P < 0.05$).

§Ethrel concentrations differ in their effects within corresponding sections ($P < 0.05$).

Table 27. Effect of Ethrel treatment on emergence and development of 12-week-old plant material under field conditions.

Plant material section	Ethrel	Growing propagules on day			Propagules with visible emerged buds situated						Dry weight on day 42	
					Above soil on day			Below soil on day			Planted propagules	Living propagules
		8	14	42	8	14	42	8	14	42		
	ppm										-------g/propagule------	
Base	0	21*§	29*§	22*§	21*§	25*§	22*	1	4	6*§	0.10*§	0.48
	3 x 10	25	32	28	24	31	27	0	1	5	0.13	0.45
	3×10^2	28	26	35	25	33	31	0	4	9	0.17	0.50
	3×10^3	10	14	11	10	13	11	0	2	1	0.04	0.38
Center	0	35§	61§	57§	34§	57§	57	0	3	13*§	0.28§	0.50
	3 x 10	37	58	55	34	52	49	2	6	23	0.35	0.64
	3×10^2	37	54	56	35	51	50	2	4	14	0.27	0.48
	3×10^3	23	34	36	23	34	34	1	0	9	0.15	0.44

*Sections differ ($P < 0.05$).

§Ethrel concentrations differ in their effects within corresponding sections ($P < 0.05$).

the quadratic regression equation fitted to the five plant materials together. These predicted optima were close enough, considering that the range covered by the tests was from 30 to 10,000 ppm, to assume that the optimum is indeed in the range from 10 to 100 ppm. Further testing would be required to find out if the optima differ with the age and section of the plant material and/or with the environmental conditions upon planting.

Weight per living propagule

The response to Ethrel of this variable followed roughly the same pattern as the weight per planted propagule. For each plant material the increase in weight per planted propagule for the highest yielding Ethrel treatment is partly or totally cuased by the increase in weight of the living propagules.

The percentage of growing propagules and the percentage of propagules with emergence of buds situated above the soil

These two related variables responded almost identically to Ethrel. The effect of the lowest and intermediate Ethrel levels varied with the plant material in an apparently random way. The overall trend indicated no response to Ethrel at these levels. The highest level in general had a negative effect ($P < 0.05$ 14 times out of 30) with the exception of the positive effect on the center section of the 7-week-old material.

Propagules with emergence of buds situated below the soil surface

The values observed for this response variable on day 8 and 14 were below 10% and did not show a response to Ethrel. At day 42 the emergence was found to have been a) increased by the intermediate Ethrel level ($P < 0.05$ for the 12-week-old plant material); b) increased by the low Ethrel level in three plant materials ($P < 0.05$ for the center section of the 12-week-old plant material); and c) reduced by the highest Ethrel level in four of the plant materials ($P < 0.05$ for the 12-week-old materials). Fitted quadratic regression equations indicated optimum Ethrel concentrations ranging from 20 to 130 ppm for the different plant materials planted at different dates. This range practically coincides with the range of the Ethrel optima for maximum propagule weight, which was discussed in an earlier paragraph to which is referred here.

Propagating capacity

In the following table the effects of the Ethrel treatment on the propagating capacities of the different plant materials are summarized.

Table 28. Summary of effect of Ethrel on the propagating capacity of plant material of three ages planted at different dates in the field.

Plant Material		Ethrel concentrations (ppm)						Calculated optimum Ethrel concentrations[§]
Plant	Section	3 x 10	10^2	3 x 10^2	10^3	3 x 10^3	10^4	
weeks		----------effect on propagating capacity[*]----------						ppm
4	Base	†	(0)++		-		--	13
7	Base		+		++		--	102
	Center		+		++		+	
12	Base	+		++		--		25
	Center	++		(0)--		--		

[*] + = improvement, ++ = maximum improvement obtained within row, - = reduction, -- = maximum reduction obtained within row, (0) = negligible change.

† Blank space indicating treatment not executed.

[§] Optimum concentration for yield per planted propagule.

CHAPTER 6
SUMMARY AND CONCLUSIONS

Studies were executed on Cynodon dactylon (L.) Pers. cv Coastcross-1 with the objectives to

1. Determine the macromorphology of individual stems and of harvested plant material.
2. Assess changes with age upon the components and the quantity of plant material.
3. Determine differences in propagating capacity among cuttings from stems different in macromorphology or from different sections of the stem.
4. Determine the effect of preplant treatment of harvested plant material with Ethrel upon the propagating capacity.

In a 3-year-old stand of Coastcross-1 three adjacent 4 x 4 areas surrounded by a 1 m border were cut back in June, 1975. Plant material 4, 7 and 12 weeks old was obtained after corresponding regrowth periods; for each age a different area was utilized.

Objectives 1 and 2 were accomplished in the following way. In each 4 x 4 m area 12 sample areas of 25 x 20 cm were randomly selected. The stems in the sample areas were cut for macromorphological description and/or weight determination. Based on the macromorphological descriptions of the stems, stem classification systems were set up, one for each age of plant material.

Propagules were grown in pots to determine differences in propagating capacity between different propagule types (objective 3). After a period of 14 days the propagules were harvested. A description of the

development or growth of apex, axillary buds and nodal roots was made, the weights of these components were also determined. Four propagule types of each plant material were studied. Each type was grown under an optimum and also under a dry moisture regime.

The effect of Ethrel treatment on plant material was studied by comparing non-treated cuttings with cuttings submerged for one minute in a Ethrel solution. Ethrel concentrations of 100, 1000 or 10,000 ppm were used in case of the 4- and 7-week-old plant material and 30, 300 or 3000 ppm in case of 12-week-old plant material.

The cuttings were 25 cm long. Only the base section of the 4-week-old material was studied. Of the 7- and 12-week-old material both the base and the center sections of the plant material were included.

Comparisons were made under an intermittent mist where the cuttings were put under 50% shade on the soil surface. Bud and root emergence observations were made and after 8 or 14 days the weight of the emerged buds and roots was determined. Comparisons were also made under field conditions. The cuttings were planted individually in 15 cm deep vertical holes in a sandy soil. Observations were made on apex growth and bud emergence and after 6 weeks the weight of the propagules was determined.

Plant material of different ages was obtained from adjacent areas. Consequently, the effects of age and area were confounded. It was assumed, however, that the differences between the adjacent areas were negligible so that the effect of age on the macromorphology and quantity of plant material could be distinguished.

Plant materials different in age were harvested on different days, namely 4, 7 and 12 weeks after June 26, 1976. Thus, the preparation and

planting of propagules different in age had to be done at different dates. Consequently, the factors age and planting date were confounded. As the environmental conditions after the planting dates were very different, the effects of age on the propagating capacity could not be distinguished, nor the effects of the difference in environmental conditions.

Increasing age of plant material resulted in a sharp decline in the quantity of living stems; from 1900 at 4 weeks to 800 at 7 weeks to 600 stems per m^2 at 12 weeks. Many stems died with increasing age of plant material. Nevertheless, both the dry weight and the number of nodes of the (living) plant material per m^2 increased with increasing age (Table 14).

With increasing regrowth period (from 4 to 7 to 12 weeks), the length, maximum diameter, number of nodes, number of nodes with emerged roots and weight of the stems increased (Table 2). From 4 to 7 weeks both the mean number of nodes with an emerged bud and those with three leaves increased. These increases were ascribed both to further development of the stems and to the fact that with ageing a higher proportion of the less well developed stems died relative to the well developed stems.

All of the macromorphological characteristics described were positively related within plant material of the same age. Generally speaking the longer a stem, the larger its diameter, the more nodes and the greater the probability that it had one or more nodes with three leaves and/or emerged roots and/or emerged buds. Nodes with three leaves occurred only at the base of the stem. Also, nodes with two leaves were never encountered below a node with three leaves. As the three leaf

phenomenum was found positively related to stem development and Stiff and Powell (1974) observed that this character may be partly genetically controlled, it seems worth further study.

Within plant material of a given age a great diversity in the macromorphology of the stems occurred. Macromorphological limits were set to distinguish specific stem classes in 4-, 7- and 12-week-old plant material (Tables 8, 9 and 10). Most of the stem classes were also different in other than the defined limits (Tables 11, 12 and 13). Macromorphological characteristics on which the classifications were based were stem diameter, presence of nodes with emerged buds or roots and number of nodes. Also, the presence of nodes with three leaves was used as a criterium. Furthermore, a class was made to separate the dead from the living stems in the 7- and 12-week old-material. The stem classes proved very useful as a means to quantitatively characterize the macromorphology of plant material.

The pot studies (Chapter 4) showed that propagules of the same stem section of different stem classes in many cases were very different in propagating capacity (more so than different sections of the same stem class). The stem diameter was found to be positively related to the propagating capacity. It was observed that within the same plant material the better developed stems had a better propagating capacity. From the few stem classes tested it was evident that the macromorphological classification of the plant material distinguished classes of stems which differed in propagating capacity.

Stems with two nodes or less formed the major proportion of the 4-week-old plant material, i.e., 96% of the stems and 90% of the weight. It was found that stem class 5, i.e., stems of two nodes with a diameter

of less than 1.3 mm, have a low propagating capacity (Table 19). Such and even less developed stems accounted for 75% of all stems, 42% of the weight and 64% of the nodes of the 4-week-old plant material. All these stems will have a propagating capacity equal to or worse than stem class 5 which developed extremely slowly even with optimum soil moisture and had a high mortality under dry conditions. It was found in the same pot test that stem class 7 and 8 have a much better propagating capacity. Propagules of these stems showed a quicker development and much lower mortality under dry conditions. The performance of these propagules under dry conditions was much better than of propagules of class 3 and 5 under optimum soil moisture conditions (Table 19). Stem class 7 and 8 together with the similar classes 9, 10 and 11 comprised 13% of the stems, 38% of the weight and 21% of the nodes of the plant material.

In the 7-week-old plant material dead stems accounted for 34% of the stems and 7% of the weight of the harvested material. The living plant material was dominated by two groups of stem classes. Stem class 23 and 25, containing stems with a diameter less than 1.6 mm and no emerged buds or roots, comprised 60% of the stems, 30% of the weight and 50% of the nodes. Stem classes 29 through 32 containing stems with a diameter of 1.6 mm or larger have a majority of stems with emerged roots and buds. They comprised 20% of the stems, 50% of the weight and 30% of the nodes of the 7-week-old material. Propagules of stem class 23 and 25 were inferior in propagating capacity to propagules of the top section of stem class 32. The last showed under dry conditions a better development than the other propagules under optimum soil moisture conditions.

In the 12-week-old material 33% of the harvested stems were dead. Approximately 25% of the (living) plant material belonged to stem classes 43 and 45, or stems with a maximum diameter of less than 1.6 mm and without emerged buds or roots. Class 43 had a maximum diameter of less than 1.3 mm and class 45 a maximum diameter ranging from 1.3 up to 1.5 mm. Another 25% of the plant material belonged to stem classes 51 and 52, containing stems ranging in diameter from 1.6 up to 2.2 mm, with emerged root(s) and with our without emerged bud(s). Stem class 56 accounted for 7% of the stems, 28% of the weight and 12% of the nodes of the living plant material. These stems had a diameter of 2.2 mm or larger with both emerged buds and roots. Stems with a diameter of less than 1.3 mm still formed a considerable proportion of this plant material, viz. 27% of the stems, 8% of the weight and 19% of the nodes.

Cuttings from the center and base section of stems of class 45 showed little difference in propagating capacity. These two propagule types 45B and 45C were inferior to propagules of the base section of stems of class 47, which had stems with emerged roots and with the same diameter range as class 45. Propagules of type 47B developed under dry conditions as well as 45B and 45C under optimal conditions. Propagules of type 51B, the base section of stems of class 51, developed under dry conditions just as well as 47B under optimum conditions. Probably propagules of stem class 56, also an important component of the material, would have been better than propagule type 51B. The findings indicate that this plant material in general had a good propagating capacity.

The pot studies showed that within each plant material stems occurred that were very different in propagating capacity. Several of these stems were killed or hardly growing under dry or even optimum soil

moisture conditions. It could be concluded from this that only a proportion of plant material planted was of significant value in obtaining quick establishment. The stems belonging to this part of the plant material could be identified by their macromorphology. That is, stems with the largest diameter and those with emerged buds and/or roots and/or nodes with three leaves gave the quickest establishment.

The management of the sward will affect the macromorphology of the plant material and it may provide a means to improve the propagating capacity. Further studies of this should be made.

Ethrel treatment was found to effect the propagating capacity of the plant material. The studies under mist showed that Ethrel stimulated early root development. The best response to Ethrel was obtained at the 300 or 1000 ppm level. In all five plant materials the 300 or 1000 ppm level was tested and resulted in an increase of the root weight of the propagules at 8 or 14 days after planting. The largest increase in root weight, 290%, was observed at 8 days on the base section of the 7-week-old plant material treated with 1000 ppm Ethrel. The effects of 1000 ppm Ethrel on root emergence, bud emergence and bud weight were different in the different plant materials and generally of little importance.

The 3000 and 10,000 ppm showed negative responses in some of the plant material. However, these levels did not have a lethal effect.

The low levels of Ethrel 30 and 100 ppm showed a response intermediate between that of the control and the intermediate Ethrel levels.

The positive effects of Ethrel treatment in the field were clearly expressed on the propagule weight at 6 weeks after planting. Zero or

minor positive effects were observed in the percentage of propagules which showed growth and/or emergence of buds situated above or below the soil.

The low Ethrel levels had a positive effect on the propagating capacity of all five plant materials tested (Table 28). The maximum improvement from the low level of Ethrel was obtained with the center section of the 7-week-old plant material where the weight of the planted propagules was increased by 38%.

In two plant materials the maximum response was obtained at the low Ethrel level. In the other three materials the maximum response occurred at the intermediate level.

The low and intermediate Ethrel treatments taken together provide ten Ethrel tests. The propagating capacity was improved in seven of these tests, negligibly affected in two and reduced in one. The maximum improvement was observed in the planting of the center section cuttings of the 7-week-old material treated with 1000 ppm Ethrel. The weight of the plants developed from these cuttings was increased by 67% compared to the control. The one negative response was observed on plant material of 4 weeks treated with 1000 ppm Ethrel where the weight of the planted propagules was decreased by 21%.

Fitted quadratic regression curves indicated that the optimum Ethrel level was between 20 and 100 ppm. This was in the lower part of the range tested. Negative effects were caused by 3000 and 10,000 ppm levels. But even at these levels, many of the stems gave new plants. So also in the field the Ethrel has a wide safety range.

The results indicate that treatment with Ethrel at levels between 30 and 100 ppm will always improve propagating capacity. Using levels

between 100 and 1000 ppm may give either positive or negative responses. It is clear that further testing of Ethrel is required to fully evaluate its benefits. Testing levels from 10 to 2000 ppm on stems different in macromorphology and/or in age and planted under different moisture regimes, seems to be most important.

GLOSSARY

Apex growth

The apex on most Coastcross-1 stems occurred within a distance of 5 cm from the top visible node. The apex is always enclosed by leaf sheaths from the top visible node and from the non-visible nodes between the top node and the apex. When new growth of these leaves is apparent the apex is growing. In the studies of the propagule types the growth of the apex was measured from the top of the propagule, below which the apex was located. This gave an underestimation of the growth which occurred above the top visible node of the propagule.

Bud emergence

A bud is situated on a node. When not emerged it is enclosed by a leaf prophyll and the adjacent leaf implanted at the base of the node. For different degrees of minuteness of description, different stages of emergence were recognized.

Non-detailed description--The bud has emerged only when the bud is visible without removal of soil or of the contiguous leaf. (This criterion was used with the macromorphological description and classification of stems for the observations on propagules during growth in the pots and for all observations on the cuttings in the Ethrel studies under mist or in the field.)

Detailed description--The bud is fully emerged when the bud is visible without removal of the contiguous leaf. The bud is semi-emerged

When the bud has broken only through its leaf prophyll. (These criteria are used with the description of propagule types before planting and other harvest.)

Compound node

A node with more than one leaf.

Dead propagules

Propagules of which all meristematic tissue from which a shoot can develop is dead.

Emerged, emergence

See bud emergence or emerged root(s).

Emerged root(s)

Root primordia are initiated and located on the node. From these, roots can develop. For different degrees of minuteness of description, different stages of emergence were recognized.

Non-detailed description--Only when the root is visible without removal of the contiguous leaf has the root emerged. (This criterion was used with the macromorphological description and classification of stems and for all observations on the cuttings in the Ethrel studies under mist or in the fields.)

Detailed description--Only when the root is visible without the removal of the contiguous leaf is the bud fully emerged. When visible only after removal of this leaf, the root is semi-emerged. (These criteria are used with the description of propagule types before planting and after harvest.)

Growing propagules

Any propagule on which new growth can be observed is growing.

Node

Definition given by Stiff and Powell (1974, p. 183).

1. That portion of the stem where a leaf or leaves are attached, although anatomically this region cannot be defined accurately.

2. To be considered that region of the stem in which many bundles have an orientation other than parallel to the long axis of the stem.

In this dissertation a node is always a visible compound node.

Nodal roots

Roots which occur on a node between elongated internodes. These roots are sometimes called "set roots" in the sugarcane literature (Van Dillewijn, 1952).

Propagating capacity

The capacity of a propagule to develop shoot and root tissue. The propagating capacity of propagules can be compared by growing them under identical conditions over the same period of time; the amount of new shoot and root tissue produced and the viability of the propagule provide bases for the comparison.

Propagule type

Propagules of the same type are propagules from similar sections of stems of the same stem class.

Roots

Roots are in this dissertation nodal roots unless they are specified as shoot roots.

Shoot roots

Roots which occur at the base of a shoot, i.e., at the base of the lowest internode of a shoot or stem.

Stem class

A stem class consists of stems the macromorphology of which meet the quantitative criteria set to define the stem class. Different stem classes were created for plant material different in age.

Stem diameter

The stem diameter is measured on an internode. Lengthwise, internodes are bobbin shaped; in cross section they are elliptic. The diameter is measured on the visible part of the internode at the most narrow point of the bobbin, generally about 1 to 2 cm below the upper node. At that point the largest width of the ellipse is taken as the diameter.

Stem diameter at the top and at 30, 60 and 90 cm

On all stems one stem diameter measurement is taken at the top of the stem, i.e., measured on the first visible node below the apex. On long stems the stem diameter if further determined at 30, 60 and 90 cm, i.e., on the internode which is located 30, 60 or 90 cm above the cut at the base of the stem.

Stem group

This is used in Chapter 3 to indicate groups of stems on which different response variables were measured. Three stem groups are distinguished. Stems of these stem groups occurred in each sample area. As a consequence of the random selection of the sample areas, chance decided if a stem belonged to a certain stem group or not.

Stem length

The stem length is measured on stems from the cut at the base to the leaf tip furthest away from the base cut.

Visible internodes

Internodes are called visible when the upper part of the internode is visible and not enclosed by a leaf sheath.

Visible nodes

Each node is enclosed by a leaf or leaves implanted at the base of the node. In addition to these leaves, leaves from a lower node can also enclose the node as long as the internode between these nodes is not elongated. The criterion for "visible" is that the node is not enclosed by leaves from a lower node. This occurs when the internode below the node is visible without having to remove leaves.

APPENDICES

APPENDIX A
THE DEVELOPMENT OF A PROPAGULE TO A NEW PLANT

Both in Chapter 4 and 5 stem cuttings were propagated and observations were made relative to their development. The following general conclusions were drawn with respect to the development of propagules after planting. Little attention will be given here to the fact that only a part of the propagules developed into a plant.

Propagule Maturity

The youngest stage at which a stem can be planted was probably represented by propagule type 3, obtained from stems of stem class 3. These stems had one visible node, an average length of 37 cm and diameter of 0.9 mm (Table 11). Under very favorable mist (Chapter 5) conditions as in the Ethrel study probably all the propagules of type 3 germinated. The 4-week-old plant material containing stems of stem class 3 had 90% emergence of bud and nodal roots (Table 22). These data show that young stems of Coastcross-1, with only one fully or partly elongated internode and one visible node, have the potential to give a new plant under optimal conditions. It was found, however, that these stems have a low propagating capacity under optimal field conditions (Chapter 4 and Table 19) and these stems will be of little or no value for field plantings. The data obtained with propagule type 8 showed that well developed stems of 4 weeks or less in age had a good propagating capacity (Chapter 4). These stems, however, were only a minor component of the 4-week-old plant material, viz. 5% by weight and 1% by stem (Table 15).

Development Sequence and Sites

When planted in soil, slightly tilted from the horizontal as in the pot study (Chapter 4) or vertically as in the Ethrel study in the field (Chapter 5), the propagules showed a certain polarity.

Leaf Growth

Propagule types 7, 8, 25A and 32A all showed further development of the apex within 10 days after planting (Tables A-7, A-9 and 20). On these propagules the axillary buds showed little or no development after planting (Tables A-1 through A-4 and A-7 through A-10). In contrast to this, on propagules with no apex, the axillary bud on the top node emerged and developed further within 14 days after planting (Tables A-3 through A-6 and A-9 through A-12). Buds situated on lower nodes showed no or little development in 14 days. All the different propagule types grown during 14 days in pots showed essentially only new leaf growth at the top of the propagule. Further elongation of top leaves occurred if the apex was present, and if no apex was present emergence and further growth occurred from the top axillary bud.

During the first 14 days the majority of the propagules planted vertically in the field also showed leaf growth only from the apex or from the bud at the top node (Chapter 5). The majority of these propagules had two visible nodes. At 2 weeks less than 2% of the growing field planted propagules showed leaf growth both from the apex and from a bud, or from two buds of the propagule. However, 6 weeks after planting, many of the same propagules viz. 45% of the growing propagules, showed growing leaves, originating both from below and above ground parts of the propagule. Consequently, between 2 and 6 weeks after

planting the development of apex or the bud at the top of the propagule was followed by activation and growth of buds situated lower on the propagule.

Six weeks after planting some propagules also showed leaf growth from new axillary buds. These axillary buds were located on new shoots which had emerged on nodes both above and below the soil. At 6 weeks these propagules showed a multiple branch shoot at the top node of the propagule and more than one shoot emerged through the soil surface.

On the propagules, which were spread on the soil surface under mist (Chapter 5), no careful check was made for any polarity or apical dominance phenomena. However, shortly after planting, namely within 8 days, leaf growth was observed at more than one node on many propagules. Possibly the exposure to light and the horizontal placement of the propagules were conditions under which apical dominance did not develop or disappeared at an early stage.

Root Growth

Spreading the propagules on the soil surface under mist (Chapter 5) allowed observations on root growth immediately following planting. On about 30% of the propagules root emergence occurred within 4 days. During this period about 20% of the buds had emerged (Tables 22, 23 and 24). Before emergence was observed the roots and buds had already been growing, hidden from the eye by the leaf sheath. So, it is obvious that both root and bud growth started shortly after planting, probably at about the same time.

The harvest after 14 days of the pot-planted propagules showed that nodal roots had developed on all growing propagules (Chapter 4, Tables

A-7 through A-12). Of the propagules with two nodes planted below the soil, root development was more active on the oldest node. Differences between the two nodes with respect to the presence of primordia or emerged roots were not detected at time of planting (Tables A-1 through A-6). There was an indication of weak basal dominance in most propagules with respect to nodal root formation. On the propagules planted under mist (Chapter 5) no attention was given to this aspect and it was only noted that on many propagules, roots had developed within 8 days on more than one node.

As indicated in the Materials and Methods section of Chapter 4, no shoot roots were found on the majority of the propagules when described 14 days after planting in pots. This is in agreement with the observation that the below ground shoots, i.e., axillary buds, of the propagule at that stage showed no or little development after planting. On several of the propagules observed after 6 weeks growth in the field some roots were found on shoots originating below the soil surface. However, the nodal roots at that stage form the major component of the root system of all growing propagules.

Some of the field planted propagules had developed long shoots from above ground buds at 6 weeks. These shoots came into contact with the soil at some distance from the propagule and grew horizontally. On some nodes, nodal roots had developed. It seemed from casual observation that these roots had not penetrated the soil to more than 5 cm depth. Possibly they served at that stage more as an anchor than as a mechanism for water and nutrient uptake.

The Propagule Stem

Both in pot and field studies in which propagules were left to grow during 2 and 6 weeks, respectively, the crucial role of the propagule stem was very striking. First of all, it served as a conduit to bring the water and nutrients, taken up by below ground nodel roots, to above ground developing buds or the growing apex. Six weeks after planting any soil moisture taken up by roots had to pass through this conduit to reach the green leaves. It was also obvious that probably all below ground bud development was made possible by photosynthates produced above ground, translocated through the propagule stem to below ground axillary buds. Probably at an early stage further development of nodal roots was at least partially made possible by above ground produced photosynthate translocated through the propagule stem. Some of the propagules grown in the pots showed very little development of the roots and comparatively speaking a disproportionate leaf development. This suggested that some water might have been taken up directly by the stem.

The Plant

From a propagule planted with one or more nodes below the soil and with above the soil one or more nodes and/or the apex, three types of plants will develop over time.

First, a plant which has the propagule stem as conduit between its roots and leaves. The roots are nodal roots developed on the below soil part of the propagule stem. The leaves emerged from the upper node of the propagule or developed from the apex of the propagule. This type

of plant developed within 14 days (Chapter 4, pot studies). Six weeks after planting the majority of the plants were found to be of this type (Chapter 5, field studies).

Six weeks after planting the propagules in the field, it was found that some shoots, emerged from buds below the soil, were developing into independent plants. This second type of plant consisted of a shoot with an etiolated part below ground and green leaves above ground. At the base of the shoot, roots developed. It was thought that at the moment of observation most of these shoots were for water and nutrient provision still partly dependent on the propagule.

On long above ground shoots often some nodes were found to be anchored to the soil by nodal roots. In several instances the bud on this node had emerged. This will give rise to a plant as observed in plantings, which were not part of this study. This third type of plant consisted of a shoot positioned above ground from which base roots have grown into the soil.

It is thought that these three types of plants will develop after any method of vegetative planting. The development speed and sequence as sketched above may possibly vary depending on the method of planting and the fertilizer used.

It is obvious that the first and third types are the most vulnerable types. They may easily be killed by grazing animals. It is interesting to note again that type 2 is for its initial development completely dependent on successful growth of type 1.

Table A-1. Propagule types in 4-week-old plant material, description and weight of stempart and buds at planting.

Propagule			Bud weight DM	Bud on top node			Bud on 2° node		
Type	Weight DM[+]	Diameter		Length	Emergence	Weight DM	Length	Emergence	Weight DM
	g	mm	mg	cm	%	mg	cm	%	mg
3	0.06a[*]	0.9a	0 a	0.2	0	0	--	--	--
5	0.12b	1.0a	0.2a	0.3	0	0.03	0.4	0	0.2
7	0.31c	1.7b	1.3b	0.7	0	0.57	0.9	0	0.7
8[§]	0.35	2.1	62.3	1.0	0	1.9	16.1	100	60.4

[+]Propagule weight not including buds and roots.

[*]Values in the same column not followed by the same letter differ ($P < 0.05$). Values not followed by a letter were not included in the statistical analyses.

[§]Values for propagule type 8 based on observations of one propagule.

Table A-2. Propagule types in 4-weak-old plant material, description and weight of roots at planting.

Type	Foot			Roots on top node					Roots on 2° node				
	Emergence	Number	Weight DM	Primordia present	Emergence	Number	Max length	Weight DM	Primordia present	Emergence	Number	Length	Weight DM
	%		mg	----------%			cm	mg	----------%			cm	mg
3	0	0	0	30	0	0	0	0	--	--	--	--	--
5	0	0	0	10	0	0	0	0	0	0	0	0.0	0
7	10	0.1	0	100	0	0	0	0	100	5	0.1	0.1	0
8[1]	50	1.0	0	100	0	0	0	0	100	50	1.0	0.3	0

[1] Only one propagule of type 8 described.

Table A-3. Propagule types in 7-week-old plant material, description and weight at planting.

Propagule				Bud on top node			Bud on 2° node				Bud on 3° node			
Type	Weight DM+	Diameter	Bud weight DM	Length	Emergence	Weight DM	Length	Dead	Emergence	Weight DM	Length	Dead	Emergence	Weight DM
	mg	mm	mg	cm	%	mg	cm	--------%	-------	mg	cm	--------%	-------	mg
23C	0.13a*	1.1a	1.0a	0.3	0	0.2	0.4	0	0	0.4	0.5	0	10	0.4
25C	0.20b	1.5b	1.8ab	0.5	0	0.4	0.6	10	5	0.7	0.7	10	5	0.7
25A	0.26c	1.5b	1.4a	0.4	0	0.2	0.5	0	0	0.5	0.5	0	0	0.8
32A	0.42d	2.0c	3.2b	0.6	0	0.3	0.8	0	0	0.9	1.0	0	10	2.0

+Propagule stem part not including buds and roots.

*Values in the same column not followed by the same letter differ ($P < 0.05$). Values not followed by a letter were not included in the statistical analyses.

Table A-4. Propagule types in 7-week-old plant material, description and weight at planting.

Type	Propagule			Roots on 2° node					Roots on 3° node				
	Root												
	Emergence	Number	Weight DM	Primordia present	Emergence	Number	Max length	Weight DM	Primordia present	Emergence	Number	Max length	Weight DM
	%		mg	-------- % --------			cm	mg	-------- % --------			cm	mg
23C	0	0	0	70	0	0	0	0	40	0	0	0	0
25C	10	0.2	0	80	5	0.1	0	0	60	5	0.1	0	0
25A	5	0.1	0	100	0	0	0	0	100	5	0.1	0	0
32A	5	0.1	0	100	0	0	0	0	100	5	0.1	0	0

Table A-5. Propagule types in 12-week-old plant material, description and weight of stem part and buds at planting.

Propagule				Bud on top node				Bud on 2° node				Bud on 3° node			
Type	Weight DM+	Diameter	Bud weight DM	Length	Dead	Emergence	Weight DM	Length	Dead	Emergence	Weight DM	Length	Dead	Emergence	Weight DM
	g	mm	mg	cm	-------%-------		mg	cm	-------%-------		g	cm	-------%-------		mg
45B	0.19a*	1.4a	1.9a	0.5	5	5	0.6	0.6	10	0	0.6	0.6	30	10	0.7
45C	0.20a	1.5a	1.2a	0.5	0	5	0.5	0.4	10	0	0.4	0.4	0	0	0.3
47B	0.20a	1.4a	2.6a	0.5	10	15	0.8	0.5	35	0	0.6	0.8	40	20	1.2
51B	0.29b	1.8b	5.0b	0.6	10	10	1.5	0.8	5	15	2.1	0.7	30	0	1.4

+Propagule stem part not including buds and roots.

*Values in the same column not followed by the same letter differ ($P < 0.05$). Values not followed by a letter were not included in statistical analyses.

Table A-6. Propagule types in 12-week-old plant material, description and weight of roots at planting.

Type	Propagule			Roots on 2° node						Roots on 3° node						
	Living roots			Primordia present	Living				Dead		Primordia present	Living				Dead	
	Emergence	Number	Weight DM		Emergence	Number	Max length	Weight DM	Number	Weight DM		Emergence	Number	Max length	Weight DM	Number	Weight DM
	%		mg	----------%			cm	mg		mg	----------%			cm	mg		mg
45B	0	0	0	50	0	0.0	0.0	0	0.0	0	60	0	0.0	0.0	0.0	0.0	0.0
45C	0	0	0	60	0	0.0	0.0	0	0.0	0	90	0	0.0	0.0	0.0	0.0	0.0
47B	20	0.2	0	90	10	0.1	0.1	0	0.6	0.1	90	10	0.1	0.1	0.0	1.8	0.3
51B	20	0.7	0.2	100	10	0.1	0.1	0	2.7	0.6	90	20	0.6	0.4	0.2	2.2	0.4

Table A-7. Propagule types in 4-week-old plant material, deacription and weight of apex and buds during growth and/or 14 days after planting under two different moisture regimes.

Propagule type	Moisture regime	Apex			Day 14			Day 14							
		New growth on day			Day 14			Bud on top node				Bud on 2° node			
		4	10	14	Dead	Developed	Weight DM	Length	Dead	Emergence	Weight DM	Length	Dead	Emergence	Weight DM
		--------cm--------			--------%--------		mg	cm	--------%--------		mg	cm	--------%--------		mg
3	Dry	0.0*	0.0	0.3	78a	0a	0.09a	0.3	92a	0a	0.1	--§	--	--	--
	Optimum	0.0	0.0	0.2	64ab	14a	0.02a	0.3	72ab	4ab	0.2	--	--	--	--
5	Dry	0.0	0.0	0.1	50bc	10a	0.02a	0.3	54bc	4ab	0.3	0.3	72a	2a	0.2
	Optimum	0.0	0.1	1.1	40bc	10a	1.0a	0.2	42c	0a	0.2	0.3	38a	1a	0.4
7	Dry	0.4	3.7	8.1	40bc	72b	18.13b	1.3	30c	12ab	1.4	0.7	64a	0a	0.9
	Optimum	0.7	6.8	13.2	20c	72b	22.96bc	2.5	18c	18ab	3.0	0.9	62a	1a	1.2
8	Dry	0.4	7.2	14.5	24c	84b	40.14c	3.3	34c	30b	7.6	16.3	44a	--	30.0
	Optimum	0.5	10.1	22.8	6c	93b	55.91c	1.9	40c	17ab	3.6	15.3	27a	--	44.4

*Values in the same column not followed by the same letter differ ($P < 0.05$). Values not followed by a letter were not included in the statistical analyses.

§--Indicates that response variable is not relevant for the corresponding propagule type.

Table A-8. Propagule types in 4-week-old plant material, description of roots and stem parts 14 days after planting under two different moisture regimes.

Propagule type	Moisture regime	Roots on top node				Roots on 2° node				Propagule weight DM+
		Emergence	Number	Length	Weight	Emergence	Number	Length	Weight	
		%		cm	mg	%		cm	mg	g
3	Dry	0a*	0.0	0.0	0.0	--§	--	--	--	0.05
	Optimum	18a	0.3	0.5	0.3	--	--	--	--	0.06
5	Dry	0a	0.0	0.0	0.0	4a	0.1	0.2	0.1	0.09
	Optimum	0a	0.0	0.0	0.0	18a	0.3	2.0	0.8	0.10
7	Dry	2a	0.1	0.0	0.0	76b	1.7	7.9	5.1	0.19
	Optimum	6a	0.1	0.2	0.1	88bc	2.2	10.3	6.1	0.20
8	Dry	34b	1.1	4.1	1.8	88bc	2.8	14.4	21.2	0.35
	Optimum	7a	0.2	0.5	0.1	100c	4.1	15.7	21.4	0.35

+Stem part only, not including buds and roots.

*Values in the same column not followed by the same letter differ ($P < 0.05$). Values not followed by a letter were not included in the statistical analyses.

§--Indicates that response variable is not relevant for the corresponding propagule type.

Table A-9. Propagule types in 7-week-old plant material, description and weight of apex and buds during growth and/or 14 days after planting under two different moisture regimes.

Propagule type	Moisture regime	Apex				Day 14											
		New growth on day		Day 14		Bud on top node				Bud on 2° node				Bud on 3° node			
						Length on day											
		9	14	Dead	Developed	9	14	Dead	Emergence	Weight DM	Length	Dead	Emergence	Weight DM	Length	Dead	Emergence	Weight DM
		cm		%		cm		%		mg	cm	%		mg	cm	%		mg
23C	Dry	—[§]	--	--	--	0.0	0.5	14	28bc	0.9	0.4	48a	12	0.4	0.3	68ab	12	0.3
	Optimum	--	--	--	--	2.0	6.2	4	92a	6.3	0.5	63b	10	0.5	0.6	79a	13	0.6
25C	Dry	--	--	--	--	0.1	1.7	0	34c	3.0	0.5	28a	4	0.8	0.6	24c	10	1.2
	Optimum	--	--	--	--	1.4	7.0	5	85d	10.4	0.6	10a	8	0.9	0.7	35bc	18	1.5
25A	Dry	0.0*	0.3	22a	4a	0.0	0.3	0	2ab	0.2	0.4	30a	0	0.5	0.5	46bc	0	0.8
	Optimum	1.4	4.3	26a	44b	0.4	0.8	4	10abc	0.6	0.5	10a	0	0.6	0.6	30bc	4	0.9
32A	Dry	1.6	4.3	0b	40b	0.0	0.5	0	0a	0.4	0.8	17a	2	1.7	1.5	46bc	19	3.4
	Optimum	2.5	8.5	4b	60b	0.0	0.5	0	0a	0.5	0.7	16a	2	1.2	1.3	28bc	8	2.9

§—Indicates that response variable is not relevant for the corresponding propagule type.

*Values in the same column not followed by the same letter differ ($P < 0.05$). Values not followed by a letter were not included in statistical analyses.

Table A-10. Propagule types in 7-week-old plant material, description and weight of roots and stem part 14 days after planting under two different moisture regimes.

Propagule type	Moisture regime	Roots on 2° node				Roots on 3° node				Propagule weight DM+
		Emergence	Number	Length	Weight DM	Emergence	Number	Length	Weight DM	
		%		cm	mg	%		cm	mg	g
23C	Dry	16ab*	0.3	0.5	0.1	6a	0.1	0.1	0	0.11
	Optimum	38abc	0.5	1.7	0.9	33ab	0.4	1.8	0.8	0.12
25C	Dry	44bc	0.6	1.3	0.8	20a	0.3	1.0	0.3	0.20
	Optimum	60c	1.0	2.6	0.7	43ab	0.8	1.9	1.1	0.21
25A	Dry	0a	0.0	0.0	0.0	16a	0.2	0.4	0.5	0.24
	Optimum	28ab	0.6	0.9	0.4	63bc	1.4	3.4	6.5	0.22
32A	Dry	2a	0.1	0.0	0.0	58bc	1.7	5.5	10.2	0.39
	Optimum	20ab	0.4	0.8	0.5	80c	2.0	6.7	8.0	0.34

+Stem part only, not including buds and roots.

*Values in the same column not followed by the same letter differ ($P < 0.05$). Values not followed by a letter were not included in the statistical analyses.

Table A-11. Propagule types in 12-week-old plant material, description and weight of apex and buds during growth and/or 14 days after planting under two different moisture regimes.

Propagule type	Moisture regime	Day 14												
		Bud on top node						Bud on 2° node				Bud on 3° node		
		Length on day			Dead	Emergence	Weight DM	Length	Dead	Emergence	Weight DM	Length	Dead	Emergence	Weight DM
		6	10	14											
		------cm------			-------%-------		mg	cm	-------%-------		mg	cm	-------%-------		mg
45B	Dry	0.2*	0.2	1.0	28a	48a	1.6	0.8	80	24	1.0	0.5	86a	8ab	0.7
	Optimum	1.4	2.9	4.2	14ab	76ab	5.3	0.6	64	16	0.8	0.6	66a	26c	1.0
45C	Dry	0.7	1.6	2.4	4b	82ab	3.5	0.5	48	8	0.6	0.4	54a	8ab	0.5
	Optimum	2.0	3.5	5.6	0b	86b	6.8	0.5	50	8	0.6	0.5	68a	4a	0.5
47B	Dry	0.7	1.3	2.5	18ab	68ab	4.4	0.8	46	18	1.6	0.6	64a	12abc	1.2
	Optimum	2.4	4.6	7.4	8b	80ab	8.3	1.0	30	22	1.7	0.8	64a	22abc	1.3
51B	Dry	1.1	2.4	4.3	8b	82b	7.6	1.0	36	18	2.3	0.9	66a	16abc	2.0
	Optimum	3.0	5.3	9.8	16ab	86b	14.0	0.9	34	26	2.1	1.2	62a	20bc	2.1

*Values in the same column not followed by the same letter differ ($P < 0.05$). Values not followed by a letter were not included in the statistical analyses.

Table A-12. Propagule types in 12-week-old plant material, description and weight of roots and stem part 14 days after planting under two different moisture regimes.

Propagule type	Moisture regime	Living roots on								Dead roots on				Propagule weight DM+
		2° node				3° node				2° node		3° node		
		Emergence	Number	Length	Weight DM	Emergence	Number	Length	Weight DM	Number	Weight DM	Number	Weight DM	
		%		cm	mg	%		cm	mg		mg		mg	g
23C	Dry	20	0.3	0.8	0.2	26	0.4	0.6	0.2	0	0	0.1	0	0.16
	Optimum	20	0.3	0.8	0.2	32	0.4	0.9	0.1	0	0	0	0	0.16
25C	Dry	14	0.2	0.4	0.2	46	0.6	1.0	0.3	0	0	0	0	0.16
	Optimum	26	0.2	0.7	0.1	64	0.8	2.4	0.5	0	0	0	0	0.17
25A	Dry	44	0.7	1.0	0.3	64	1.0	1.9	0.7	0.8	0.2	2.1	0.5	0.18
	Optimum	56	1.1	2.0	0.9	56	1.1	2.7	1.2	1.2	0.2	1.4	0.5	0.19
32A	Dry	44	0.8	1.4	0.5	72	1.6	2.6	1.5	1.9	0.5	2.4	0.4	0.27
	Optimum	58	1.5	2.3	0.8	72	1.6	3.4	2.0	1.6	0.4	2.2	5.1	0.28

+Stem part only, not including buds and roots.

APPENDIX B
PRELIMINARY TESTS OF THE EFFECT OF GROWTH REGULATORS ON THE VEGETATIVE PROPAGATION OF GRASSES

Preliminary tests were conducted to find a growth regulator treatment increasing the propagating capacity of stem propagules of tropical grasses.

Growth Regulator Effects on Cuttings of Digitaria decumbens Stent. cv Pangola

One node propagules were cut from the third and seventh node below the top of flowering Pangola stems. The propagules were submerged during one minute in a growth regulator solution. Indolebutyric acid (IBA) and Ethrel were tested at concentrations of 100, 300 and 3000 ppm and benzyladenine (BA) at concentrations of 30, 100 and 1000 ppm in solutions containing, respectively, 1, 5 and 50% alcohol. Untreated propagules and propagules submerged during one minute in a 10% alcohol solution were used as a check. Eight propagules were used in each of the 22 treatments.

The development of the propagules was studied over a period of 28 days during which the propagules were suspended vertically in an aerated nutrient solution. The lower part of the propagule node was at the solution level. This enabled roots to grow out into the solution whereas all or most of the bud was above the solution.

Four days after planting the leaf was removed from the propagules so that the contiguous axillary bud could be observed. Bud development of several propagules had started within the first 4 days upon planting. On 90% of the propagules one to five nodal roots had emerged within 8

days upon planting. Shoot roots emerged later, 28 days after planting they were present on only 20% of the growing propagules.

Treatment means indicated the following:

1. BA at all concentrations, IBA and Ethrel at 3000 ppm suppressed propagule development and caused increased propagule mortality. These adverse effects were most pronounced in the propagules of the upper stem section.

2. IBA and Ethrel at 100 and 300 ppm promoted early root emergence and root growth, and increased both total number and total weight of roots. IBA initially suppressed bud development.

3. The favorable effects of IBA and Ethrel were most pronounced on the propagules cut from the base section of the Pangola stems.

The difference between the control treatments and the best growth regulator treatments was in the order of a factor two for several of the responses measured; even so, the treatment responses were not significant at the 5% probability level. The coefficient of variation within the treatments ranged for most responses from 40 to 100%.

Response to Ethylene Treatment of Propagules from Six Different Grasses

One node propagules were cut from the base and upper section of stems of each of the following grasses:

Cynodon dactylon (L.) Pers. cv. Coastcross-1
Cynodon nlemfuensis Vanderyst var. nlemfuensis
Digitaria decumbens Stent. cv. Pangola
Digitaria decumbens Stent cv. Transvala
Hemarthria altissima (Poir.) Stapf et C. E. Hubb. P. I. 299994
Hemarthria altissima (Poir.) Stapf et C. E. Hubb. P. I. 299995

The propagules were enclosed for 4 days in different Erlenmeyer flasks with ethylene gas levels of 0, 5, 10 and 20 ppm in water saturated air. Five propagules were used in each of the 48 treatments.

After ethylene exposure the propagules were grown for 9 days in pots. The variation within the treatments was very large and no conclusions could be drawn with respect to species, stem section or optimum ethylene level. Of the 12 different plant materials studied (6 cultivars x 2 stem sections), 11 responded positively to ethylene. Only one, the base section of Pangola stems, showed a reduction of root development in the ethylene treated propagules.

Response to Ethylene Treatment of Coastcross-1 Propagules

Forty cm long Coastcross-1 stems were harvested in early June from a nitrogen deficient stand. Twenty cm long propagules were prepared and exposed during 2 days to ethylene concentrations 0, 100 and 1000 ppm in water saturated air. After exposure the propagules were placed horizontally on a bench and were wetted by misting four times a day. Each treatment was replicated three times with approximately 100 propagules per replication. Five and 11 days after harvest the root and the bud emergence were checked. No response to treatment was observed.

Forty cm long Coastcross-1 stems were harvested in mid June from a medium to well fertilized stand. Twenty cm long propagules were prepared and exposed for 4 days to ethylene concentrations of 0, 100 and 1000 ppm in water saturated air. After this the same procedures were followed as those harvested in early June. Nine days after harvest root and bud emergence were checked. The exposure to ethylene produced approximately a two-fold increase in root emergence and a three-fold increase in bud emergence.

Response to Ethrel Treatment of Coastcross-1 Propagules

Forty cm long Coastcross-1 stems were harvested in late June from a well fertilized stand. Twenty cm long propagules were submerged for one minute in an aequous Ethrel solution of 0, 30, 300 or 3000 ppm. Planting procedures were identical to those in the previous studies with ethylene. Five days after planting root and bud emergence were checked. The 3000 ppm Ethrel treatment produced approximately a two-fold increase in both root and bud emergence. The response to the 300 ppm Ethrel treatment was in between the control and the 3000 ppm treatment. The 30 ppm treatment did not differ from the control.

REFERENCES

Abeles, F. B. 1973. Ethylene in plant biology. pp. 302. Academic Press, London and New York.

Anonymous. 1976. 1975 climatological data for Gainesville, Florida and B.R.U. Agronomy Research Report AG 76-2:13. IFAS, University of Florida, Gainesville.

Arcenaux, G. 1948. Some practical means of improving stands of sugarcane under Louisiana conditions. Sugar Bull. Louisiana 26:404-413.

Barnard C. ed. 1964. Grasses and grasslands. pp. 269. MacMillan and Co. Ltd., London and Melbourne.

Barnes, A. C. 1974. Agriculture of the sugarcane. pp. 572. John Wiley and Sons, New York.

Bernal, E. J. 1971. Para grass methods of vegetative propagation. Revista Instituto Columbiano Agropecuaria 6:149-155.

Bogdan, A. V. 1952. Observations on stoloniferous grasses in Kenya. East Afr. (Uganda) Natur. Hist. Soc. J. 20:71-76.

Burton, G. W. 1972. Registration of Coastcross-1 bermudagrass. Crop Sci. 12:125.

Chiles, R. E., Huffine, W. W. and Lynd, J. Q. 1966. Differential response of Cynodon varieties to type of sprig storage and planting depth. Agron. J. 58:231-234.

Chew, N. P. 1950. Number of buds per seed piece in relation to germination growth and yield of sugarcane. Reports Taiwan Sugarcane Exp. Sta. 5:91-108.

Chew, V. 1976. Comparing treatment means--A compendium. Techn. Rep. No. 105. pp. 43. Agric. Res. Serv. USDA and Dept. of Statistics, Univ. of Florida, Gainesville, Florida, USA.

Domir, S. C. and Foy, C. L. 1975. A study of ^{14}C-ethylene and $^{14}CO_2$ evolution from ^{14}C-Ethepon. Abstract 37. Division of Pesticide Chemistry. American Chemical Society 107th National Meeting. Chicago, Illinois.

Dutt, N. L. 1934. Recent advances in sugarcane breeding in India. Proc. Assoc. Econ. Biologists 2:1-7.

Evans, M. W. 1958. Growth and development in certain economic grasses. pp. 108. Agronomy Series No. 147, Ohio Agric. Exp. Sta., Wooster, Ohio.

Fuller, W. F. 1973. Cold hardiness in common Bermudagrass rhizomes. pp. 116. Dissertation Abstracts International 34:4786-B.

Gaskins, M. H. and Almeyda, N. 1972. Propagating tropical bamboo species from culm segments and lateral shoots. Florida State Hort. Soc. 85:303-305.

Gould, F. W. 1968. Grass systematics. pp. 382. McGraw-Hill Book Company, New York.

Grether, T. 1967. Stolons and vegetative reproduction of turfgrass. North-west Turfgr. Conf. Proc. 21:59-63.

Heideman, G. S. and Van Riper, G. E. 1967. Bud activity in the crown, stem and rhizome tissue of switchgrass. J. Range Mngt. 20:236-241.

Horowitz, M. 1972. Effects of desiccation and submergence on the viability of rhizome fragments of Bermudagrass and Johnson grass and tubers of nutsedge. Israel Journ. of Agric. Research 22:215-220.

Hoveland, C. S. 1963. Effect of 3-indolebutyric acid on shoot development and rooting of several Bermudagrasses. Agron. J. 55:49-50.

Hovin, A. W., Beck, B. E. and Marten, G. C. 1973. Propagation of Reed Canarygrass (Phalaris arundinacea L.) from culm segments. Crop Sci. 13:747-749.

Johnson, B. G. 1958. Natural and induced rhizome bud dormancy in Agropyron repens (L.) Beauv. pp. 162. Dissertation Abstracts International 19:1505-B.

Khan, M. A. and Hall, W. C. 1954a. Effect of growth regulators on germination (axillary bud growth) and root development of sugarcane stem cuttings. Bot. Gazette 115:261-271.

Khan, M. A. and Hall, W. C. 1954b. Response of sugarcane cutting to auxin treatment as modified by other applied compounds. Bot. Gazette 116:172-183.

Madison, J. H. 1971. Practical turfgrass management. pp. 461. Van Nostrand Reinhold Co., New York.

McAffee, T. A. 1973. Use of Ethepon (2-chloroethylphosphonic acid) as an inhibitor of plant height for Kentucky Bluegrass, Poa pratensis L. pp. 60. Dissertation Abstracts International 35:19-B.

Phillips, I. D. J. 1975. Apical dominance. Annual review of plant physiology 26:341-367.

Service, J. 1972. A user's guide to the statistical analysis system. pp. 260. Student Supply Stores, Raleigh, North Carolina, USA.

Sprague, H. B. 1970. Turf management handbook. pp. 253. The Interstate Publishers, Danville, Illinois, USA.

Stiff, M. L. and Powell, J. B. 1974. Stem anatomy of turfgrass. Crop Sci. 14:181-187.

Swanson, Jr., B. 1974. Ethrel as an aid in rooting. The Internat. Plant Propagators' Soc. Combined Proceedings 24:351-361.

Van Dillewijn, C. 1952. Botany of sugarcane. pp. 371. Waltham, Mass., USA.

Venkatraman, T. S. and Thomas, R. 1922. Sugarcane and root systems. Studies in development and anatomy. Agric. J. India 17:381-388.

Verdooren, L. R. 1963. Extended tables for Wilcoxon's test statistic. Biometrika 50:177-186.

Vlitos, A. J. 1974. A review of plant growth regulating chemicals in sugarcane cultivation. Proc. Internat. Soc. of Sugar Cane Technologists 15:932-937.

Weller, D. M. 1927. An interesting habit of sugarcane roots. Reports Assoc. Hawaian Sugar Techn. 6:73-79.

Zimmerman, P. W. and Hitchcock, A. E. 1933. Initiation and stimulation of adventitious roots caused by unsaturated hydrocarbon gasses. Contributions from Boyce Thompson Institute 5:351-369.

BIOGRAPHICAL SKETCH

Heko W. Koster was born in Amsterdam, Holland, on October 5, 1937. He graduated from the Kennemer Lyceum in 1956. He spent 18 months in the Dutch army as a soldier, after which he worked as a sailing instructor.

In 1958 he enrolled as a student in the Landbouwhogeschool at Wageningen. He received his Ingenieurs degree in 1968 with a major in pedology of the tropics. He worked as associate expert and expert in pasture improvement projects of the Food and Agricultural Organization in Taiwan and Panama in the years 1968 through 1973. In June, 1973 he accepted a graduate research assistantship at the University of Florida to pursue the Doctor of Philosophy degree in Agronomy.

He married Anneke van Lier in 1968 and they have two children. He is a member of the Royal Netherlands Society for Agricultural Science, American Society of Agronomy, Crop Science Society of America, International Soil Science Society, Soil and Crop Society of Florida and Gamma Sigma Delta.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Gerald O. Mott, Co-chairman
Professor of Agronomy

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Murry H. Gaskins, Co-chairman
Professor of Agronomy

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality as a dissertation for the degree of Doctor of Philosophy.

Clarence B. Ammerman
Professor of Animal Science

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality as a dissertation for the degree of Doctor of Philosophy.

Darrell E. McCloud
Professor of Agronomy

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Woodrow W. McPherson
Graduate Research Professor of
Food and Resource Economics

This dissertation was submitted to the Graduate Faculty of the College of Agriculture and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

June, 1976

Jack L. Fry
Dean, College of Agriculture

Dean, Graduate School